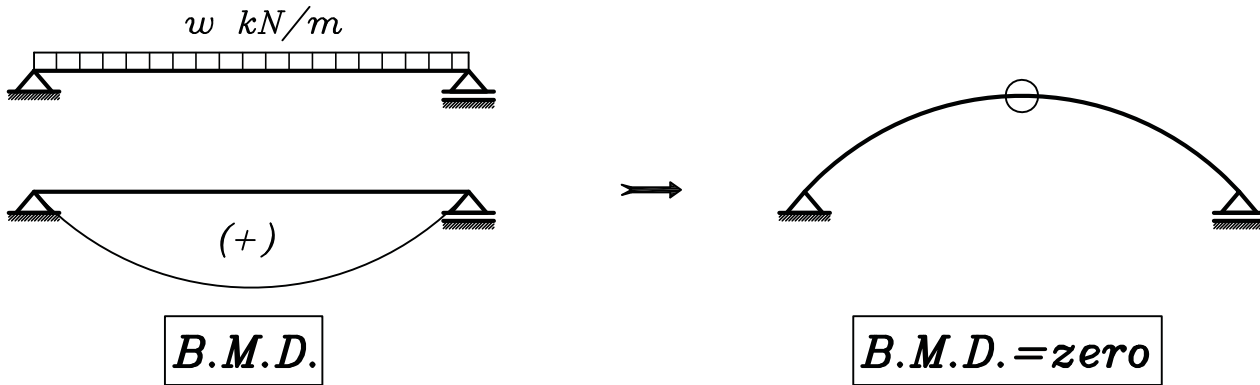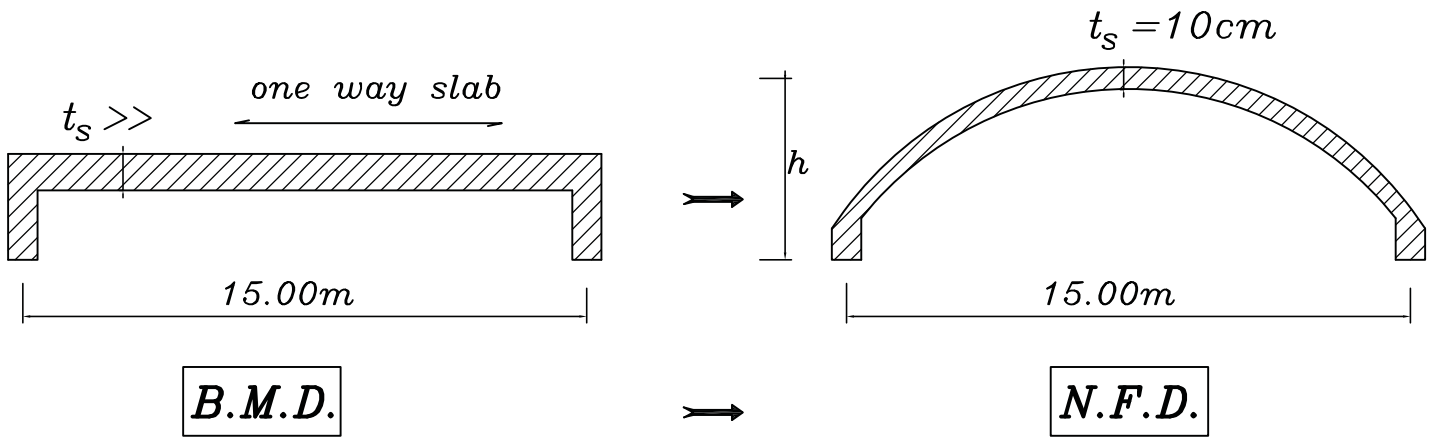# Arch Slab
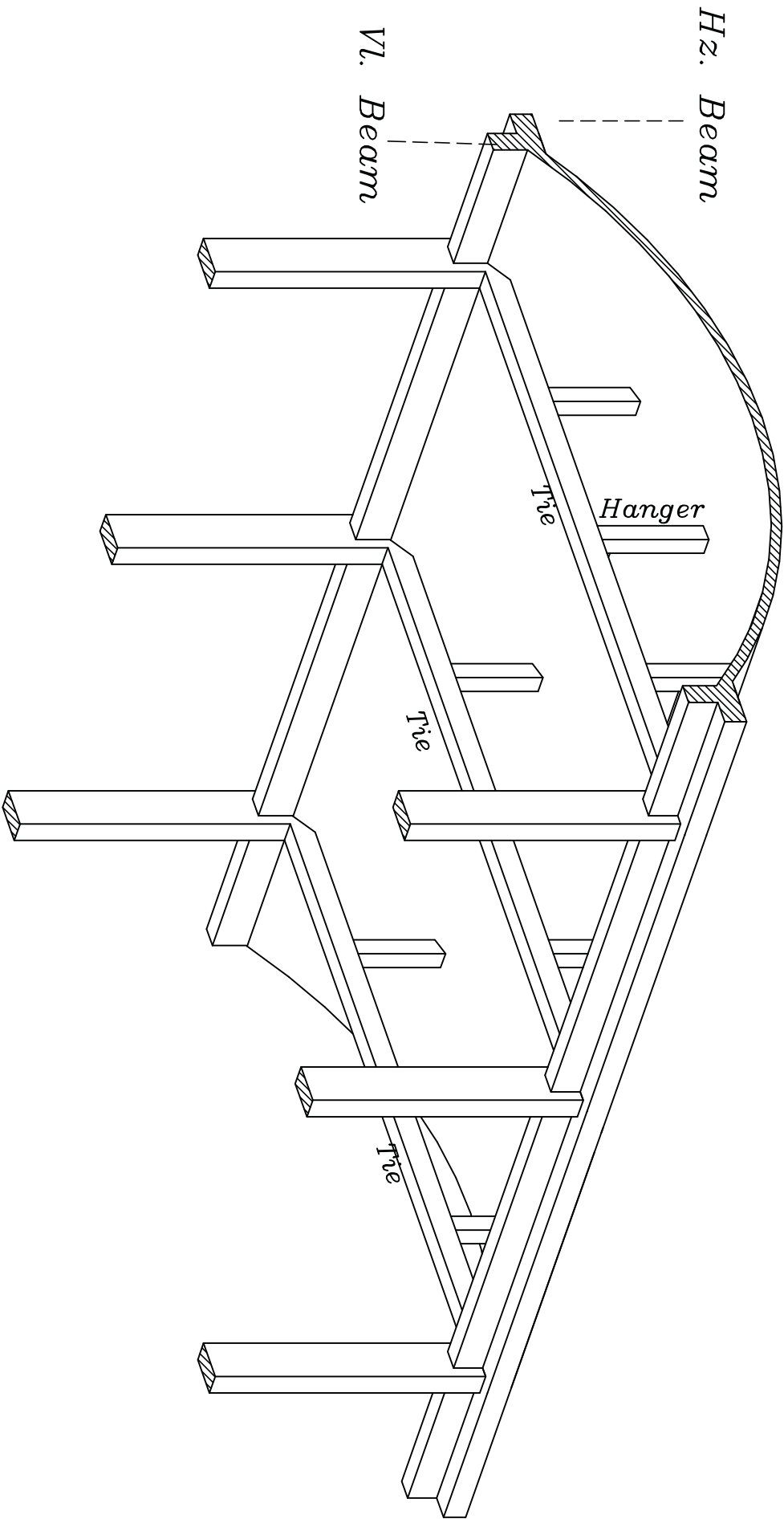
اى منشأ (بلاطة او كمرة) تم عمله على شكل مقلوب الـ .B.M.D
سوف نحصل على منشأ عليه .B.M.D يساوى صفر تقريبا
و لكن معرض الى .N.F   ضغط فقط

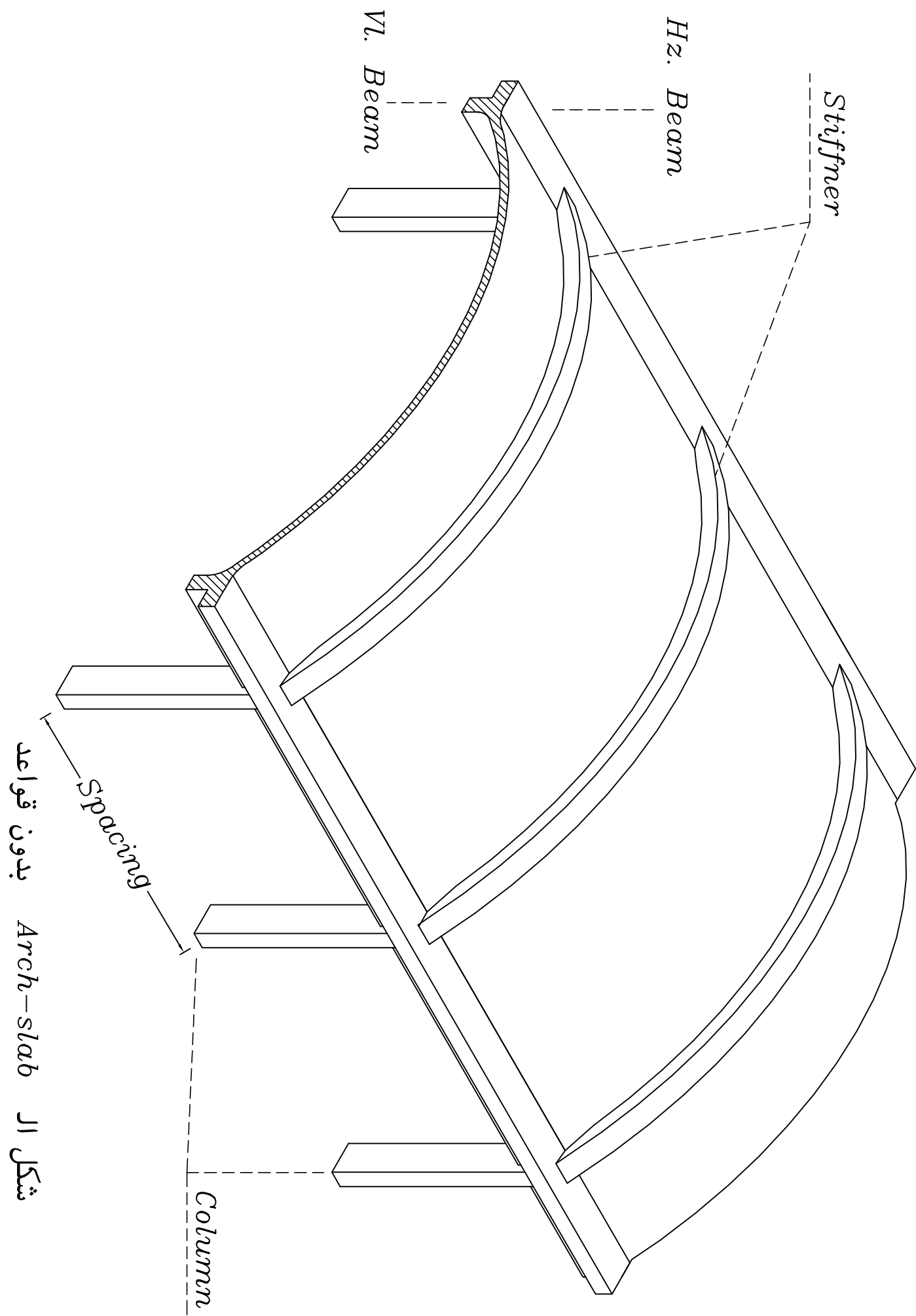# How Arch slab works

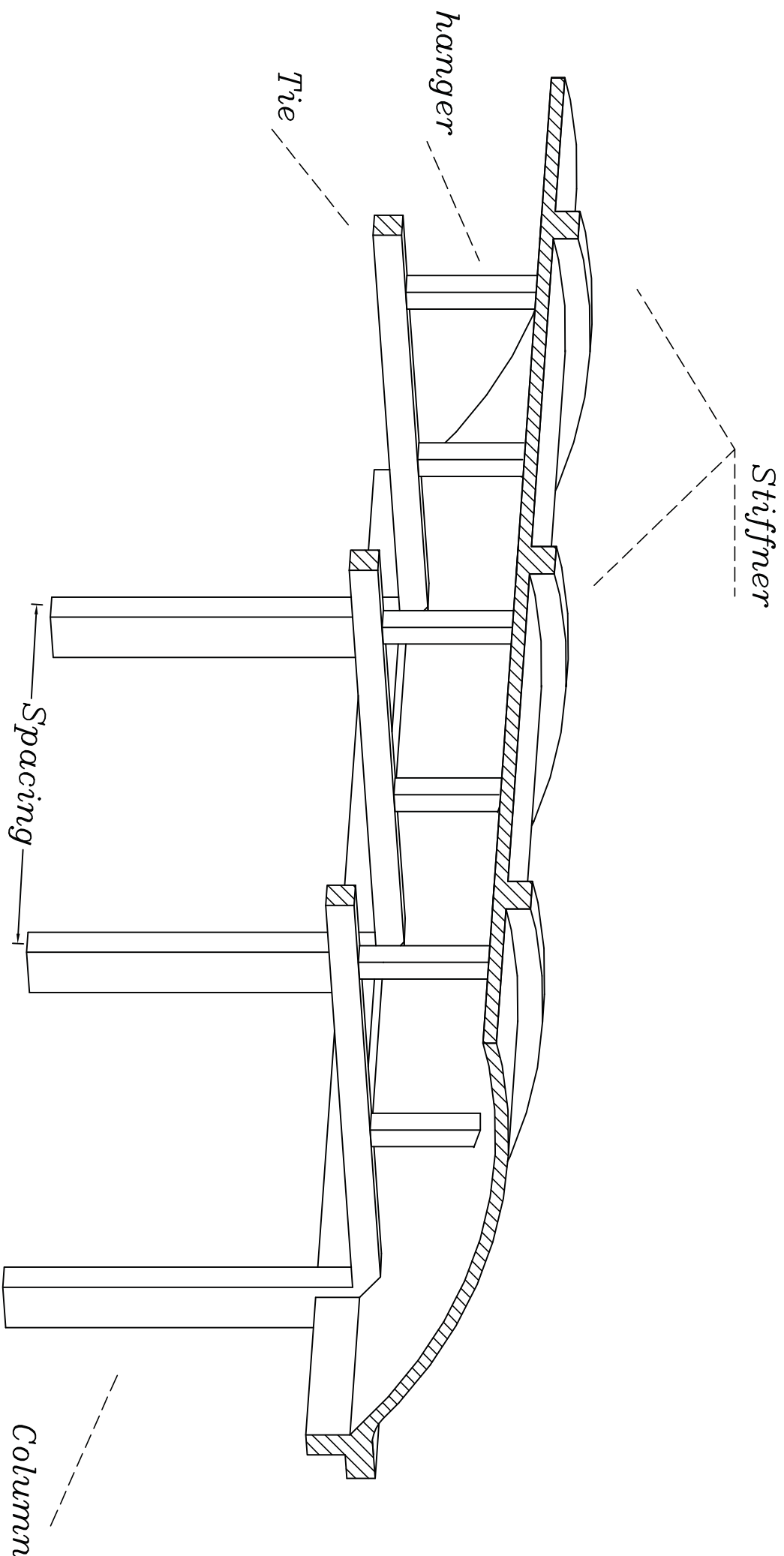

عندما يكون لدينا بلاطة (One way slab) ذات طول كبير فان سمك
البلاطة سوف تكون كبيرة جدا وبالتالى تكون ذات وزن ثقيل جداولكن عندما
تتحول هذه البلاطة الى (Arch slab) اى مقلوب شكل (.B.M.D) تصبح البلاطة
عليها (N.f) فقط وبالتالى تكون التخانة صغيرة جدا .

Hz. Beam
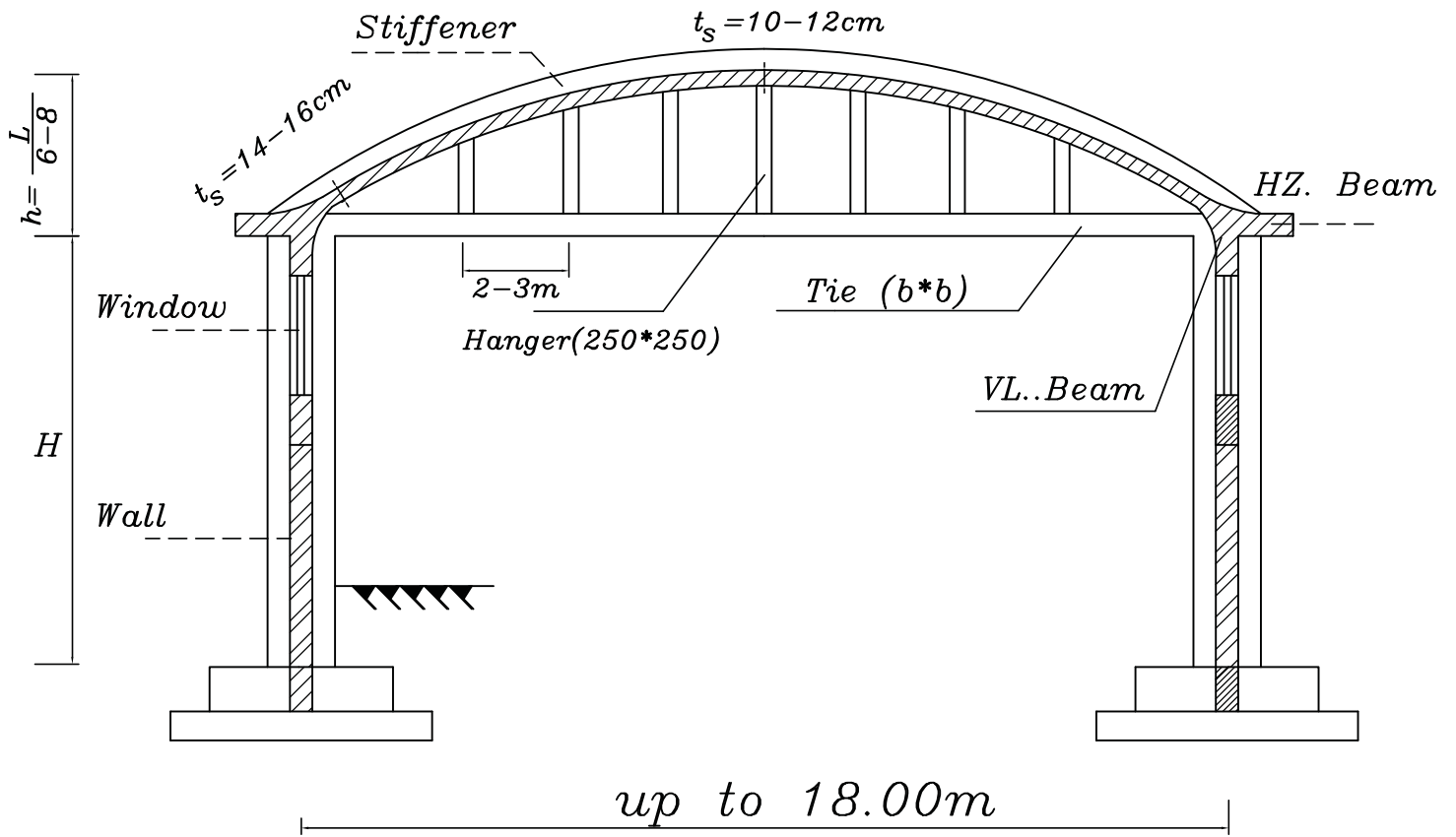
Vl. Beam

Tie

Hanger

Tie

Tie

بنوع قواعد Arch-slab شكل ال

Vl. Beam

Hz. Beam

Stiffner

Spacing

Arch-slab تشكيل الواح

Column

hanger

Tie

Stiffner
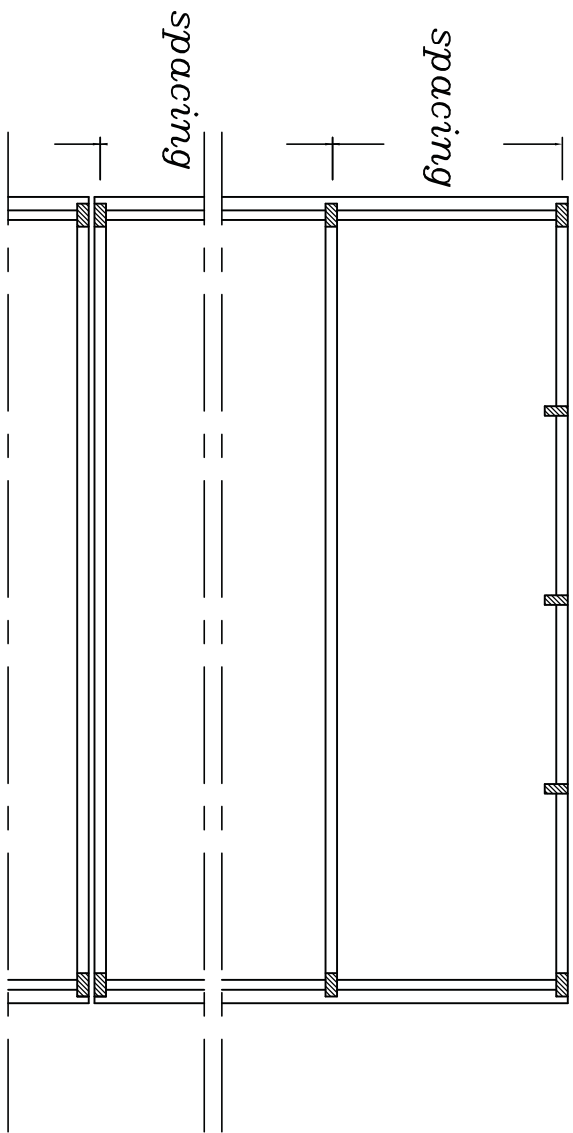
Spacing

Column
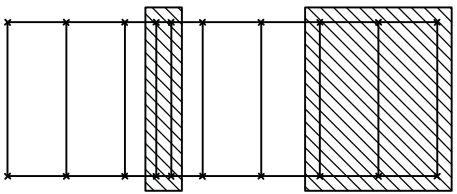
Arch-slab ال الطويل الاتجاه في يعمل قطاع

up to 18.00m

Arch slab is used for span up to 18 m

Concrete Dimensions

- t_s (10−12cm) at mid span and (14−16cm) at edges.
- $h = \dfrac{L}{6-8}$
- Tie (b*b), hager(250*250mm)
- $t(col) = \dfrac{H}{12}$
- Staticl system
- Stiffner (250*400)
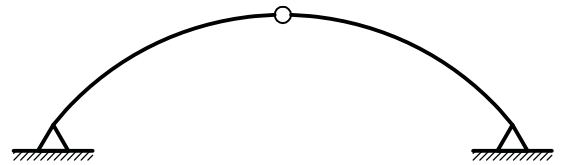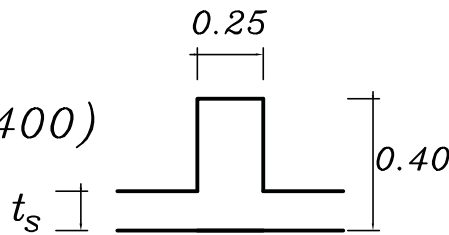
يوضع (Stiffner) لتقوية البلاطة ويقلل (Buckling) للبلاطة ويتم وضعها

(hangers) فوق

spacing   spacing

$\overline{(0.00)}$

KEY PLAN

1:200 ⟶ 1:400

Plan

spacing

spacing

Elevation

up to 18.00m span

$\overline{(0.00)}$

Side view

spacing

spacing   spacing

(0.00)

KEY PLAN

1:200 → 1:400

Plan

spacing

spacing

(0.00)

Case of arch slab without tie
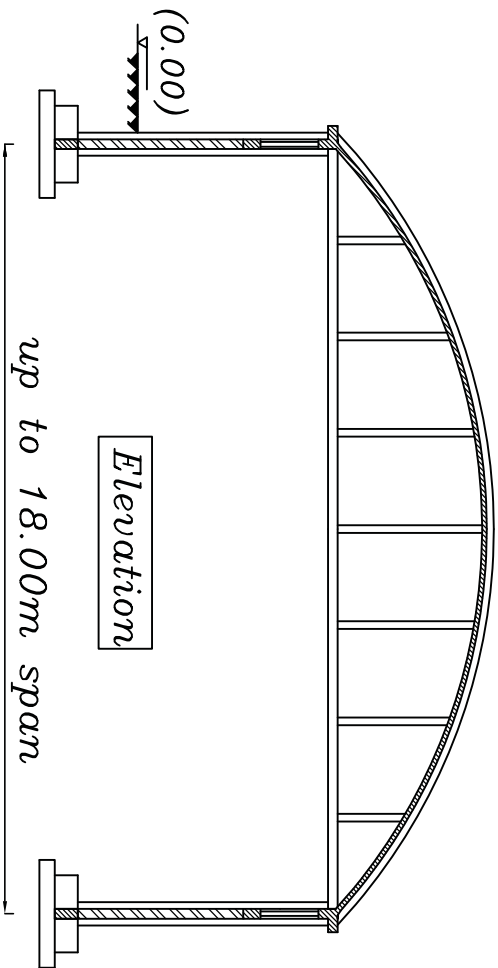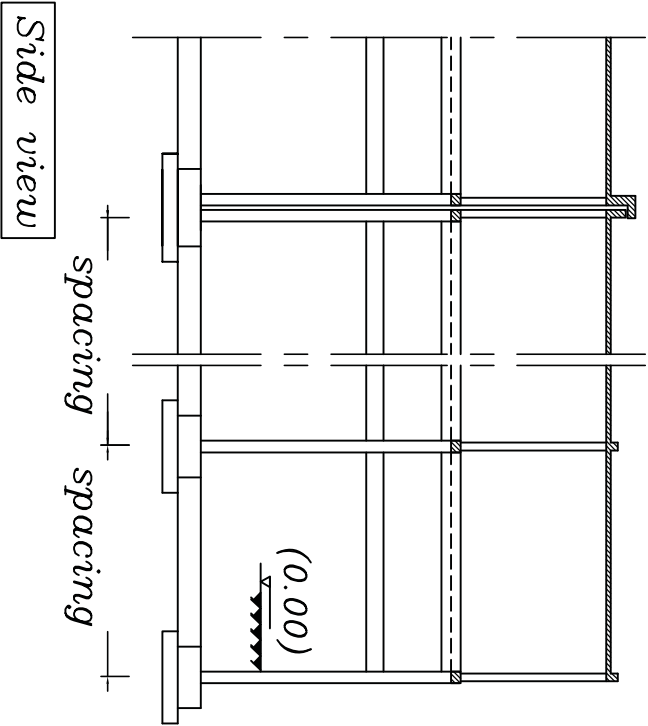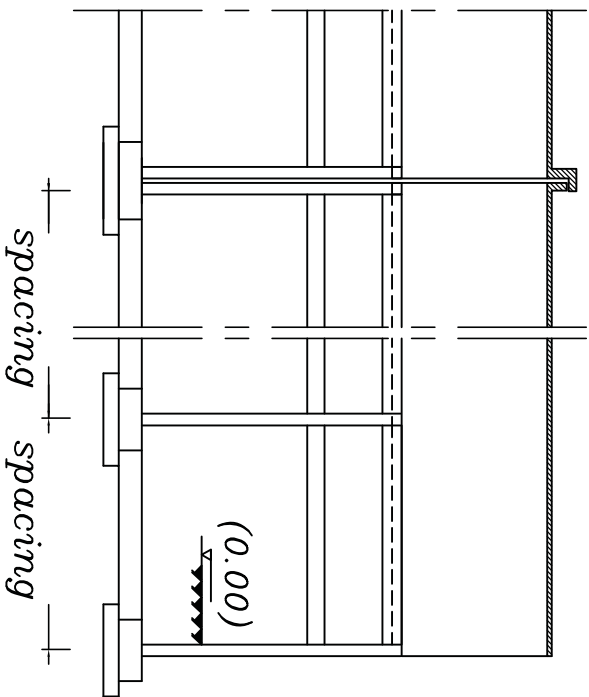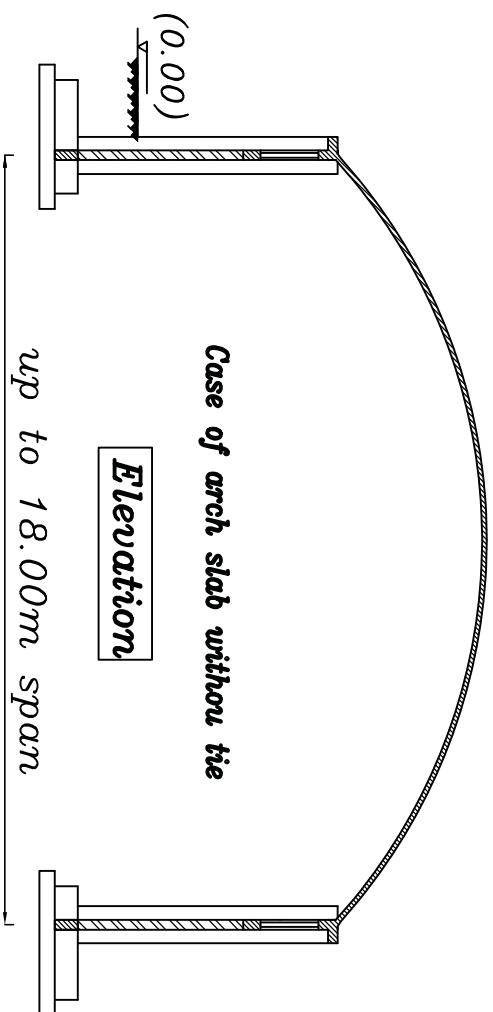
Elevation
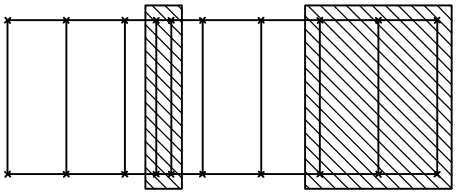
up to 18.00m span

How To draw Arch slab

a- Mathematical Method
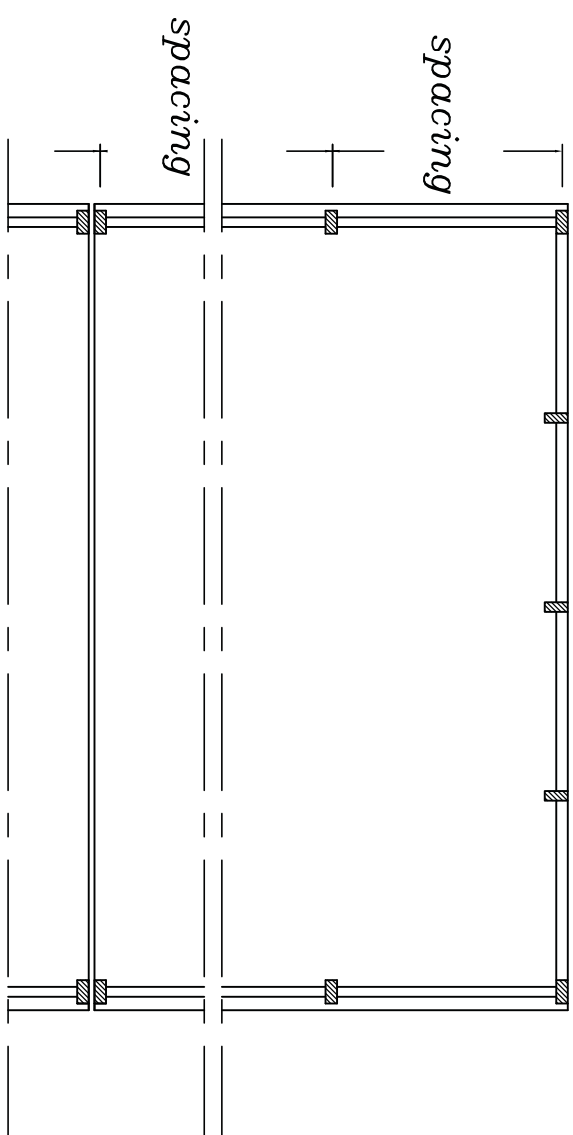

$$y = a\ X^2$$

$$\text{at}\ \ X = \frac{L}{2}\ ,\ \ y = h \quad \longrightarrow \quad h = a\ \frac{L^2}{4} \quad \longrightarrow \quad a = \frac{4h}{L^2}$$
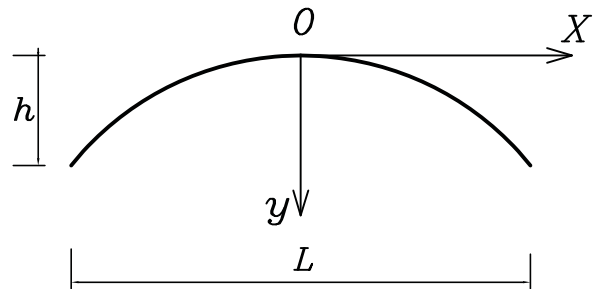
$$\boxed{y = \frac{4h}{L^2}\ X^2}$$

<div dir="rtl">بالتعويض بقيم مختلفة لـ (X) يتم ايجاد الارتفاعات المقابلة.</div>

b-graphical Method
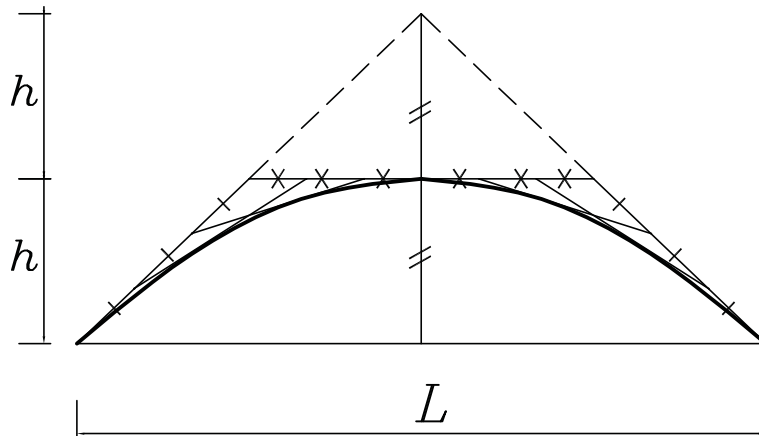
Steps of design

$$\text{assume}\ \ F.C. + L.L. = 1.0 - 1.5\ \ kN/m^2\ \ \text{per hz projection}$$

$$w_{su} = (t_s\ \gamma_c\ + F.C. + L.L.) * 1.5\ \ kN/m^2 \quad \text{per hz projection}$$

$$y = \frac{w_{su} \cdot L}{2} \quad kN/m'$$

$$x = \frac{w_{su} \cdot L^2}{8h} \quad kN/m'$$

$$\boxed{R = \sqrt{x^2 + y^2}}$$

w_{su}

h

$x \quad\quad x$
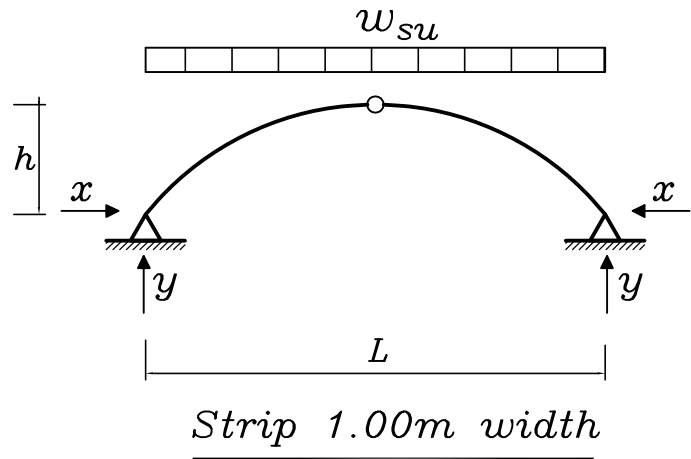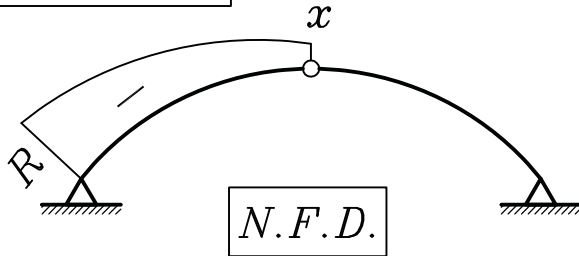
$y \quad\quad y$

L

Strip 1.00m width

x

R

$\boxed{N.F.D.}$

1—Design of Arch slab:

$$R = 0.35 \; A_c \, f_{cu} + 0.67 \; A_s \, f_y$$

$$R = 0.35 \; (1000 * t_s) \, f_{cu} + 0.67 \; A_s \, f_y$$

$$get \quad A_s \; \not< \; \frac{0.6}{100} \; A_c$$

$$A_s \; \not< \; 5\phi 8/m'$$

2—Design of VL.Beam:

$w_v \; kN/m'$

spacing $\quad$ spacing

R_v
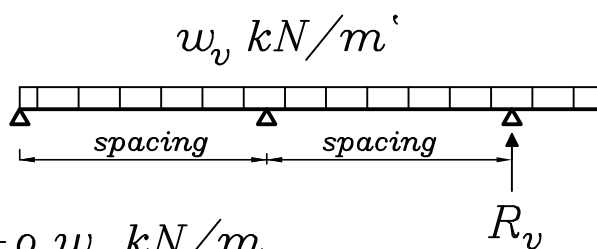
$$w_v = y + o.w \quad kN/m$$

where $o.w = o.w$ of $(VL+HZ \; beam)$

$$R_v = w_v * spacing$$

$y \; kN/m$
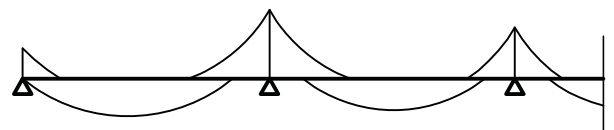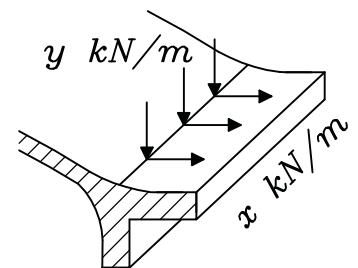
$x \; kN/m$

3—Design of HZ.Beam

$$w_{hz} = x \quad kN/m$$

$$R_{hz} = w_{hz} * spacing$$

4—Design of Tie

$$T_{u.L.} = R_{hz} = w_{hz} * spacing$$

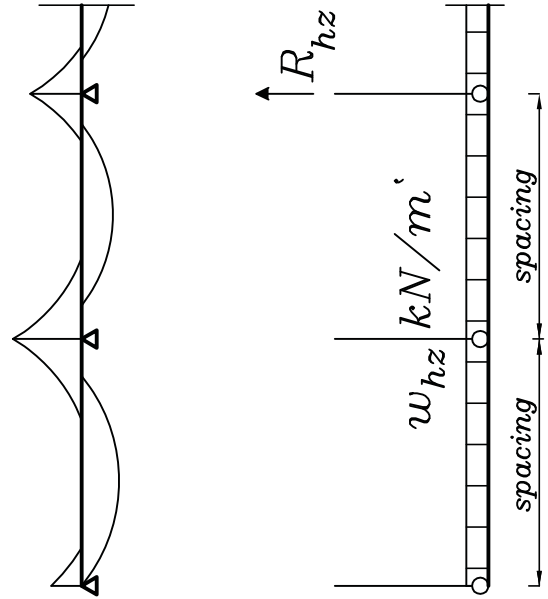$$A_s = \frac{T_{u.L.}}{f_y / \gamma_s}$$

5—Design of hanger

$$T = o.w \text{ of } hanger + o.w \text{ of } Tie \text{ .} a$$

$$T = 0.25^2 * h * 25 * 1.4 + 0.30^2 * a * 25 * 1.40$$

$$A_s = \frac{T_{u.L.}}{f_y / \gamma_s}$$

6-Design of col.

$$N_{ul.} = R_v$$

Inside plane

Case(2)

H

Case(1)
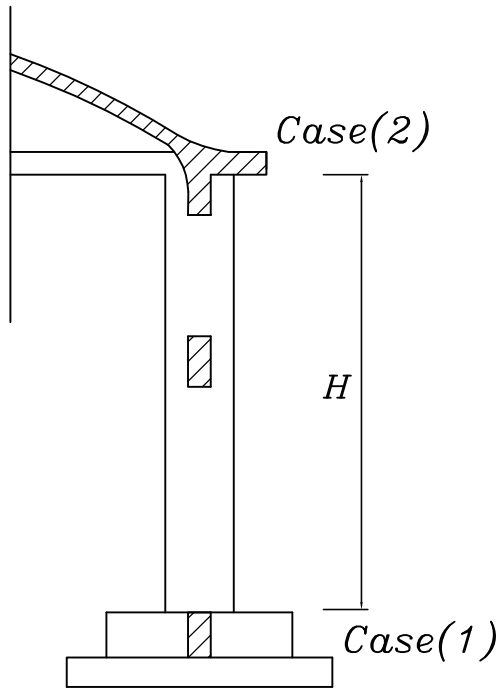
$$\lambda_{b_{in}} = \frac{1.3*H}{t}$$

Outside plane

Case(1)

h_2

Case(1)

h_1

Case(1)
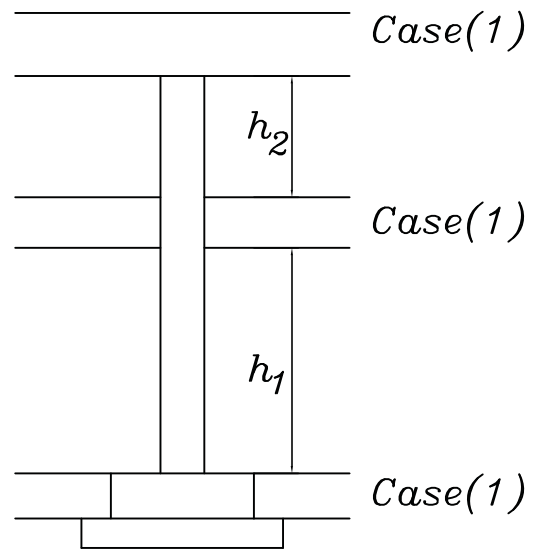
$$\lambda_{b_{out}} = \frac{1.2*h_{max}}{b}$$

Design section on $N_{u.l.}$, M_{add}

R.F.T. of the Arch slab

Detail (B)

OR

Sec.1-1

2φ12

2φ12

0.25

0.40

Sec.2-2

0.25

0.25

Sec.3-3

0.30

0.30

Detail (B)

2 — 2

3 — 3

1 — 1
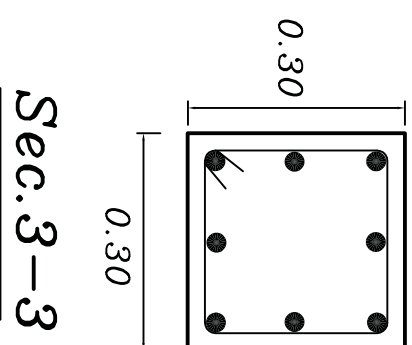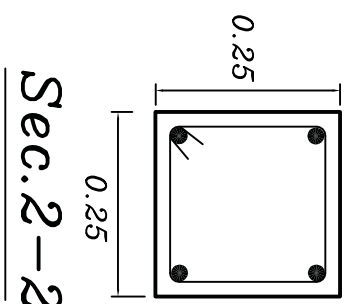
Sec.1-1

Sec.2-2

Plan of Rft. for HL. Beam

Plan

Tie

Elev. of Rft. for VL. Beam

Elevation

Column

2 — 2

1 — 1
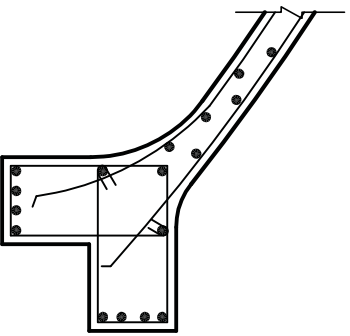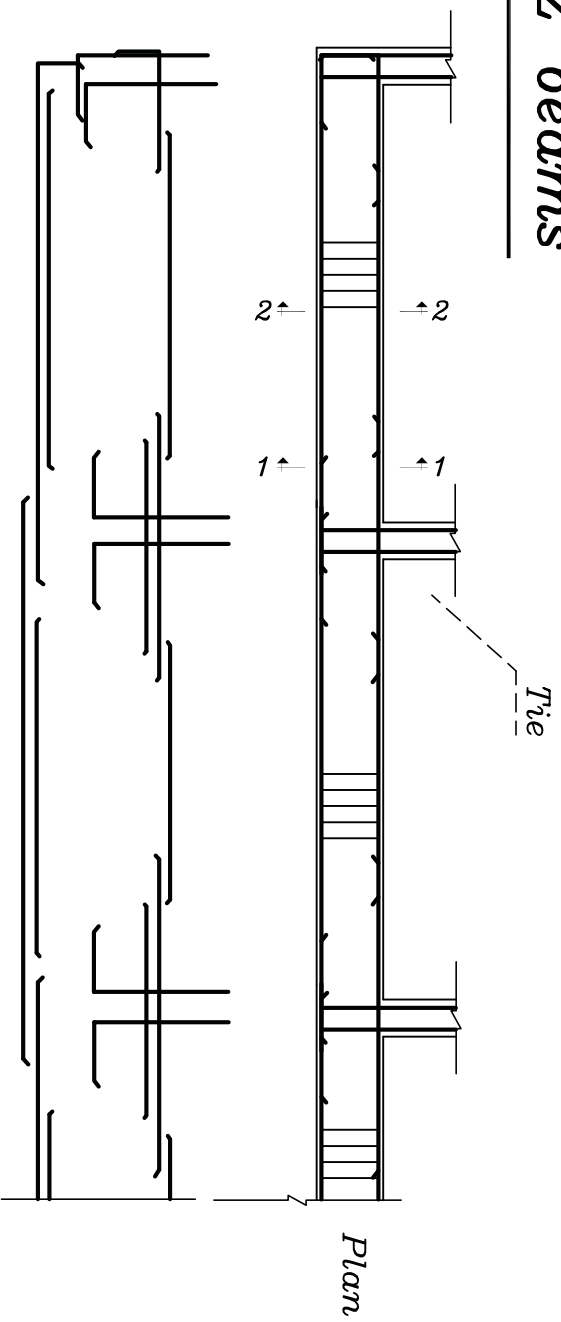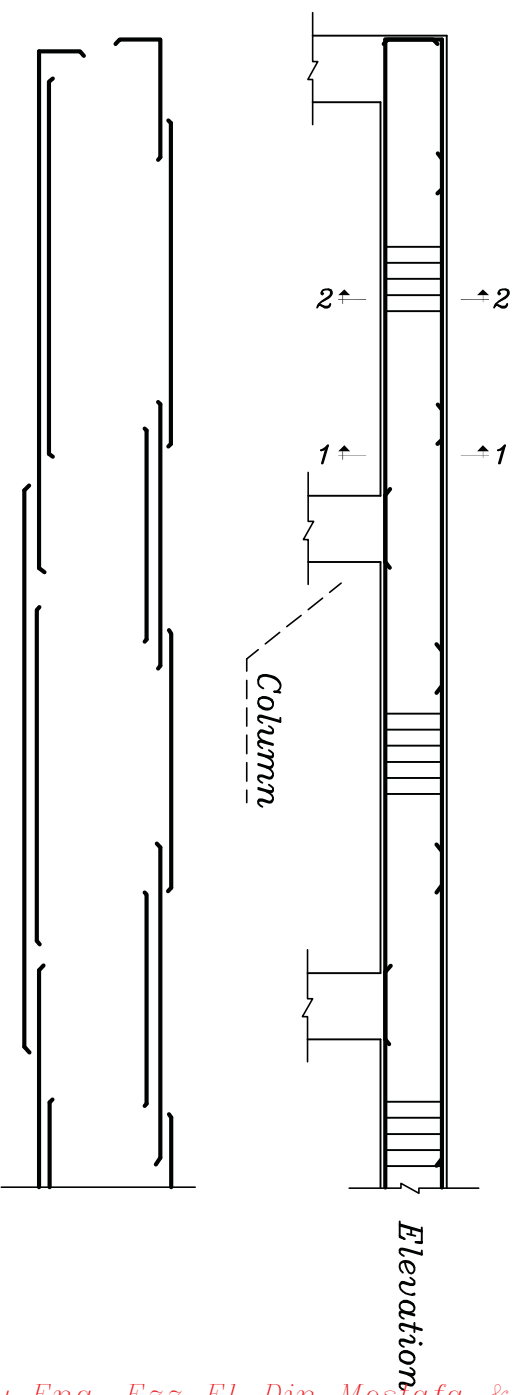
Some Special Cases

1- If There is no Tie

R_v

R_{hz}

H

$R_{hz}*H$

عمود كبير
لمقاومة العزم

H
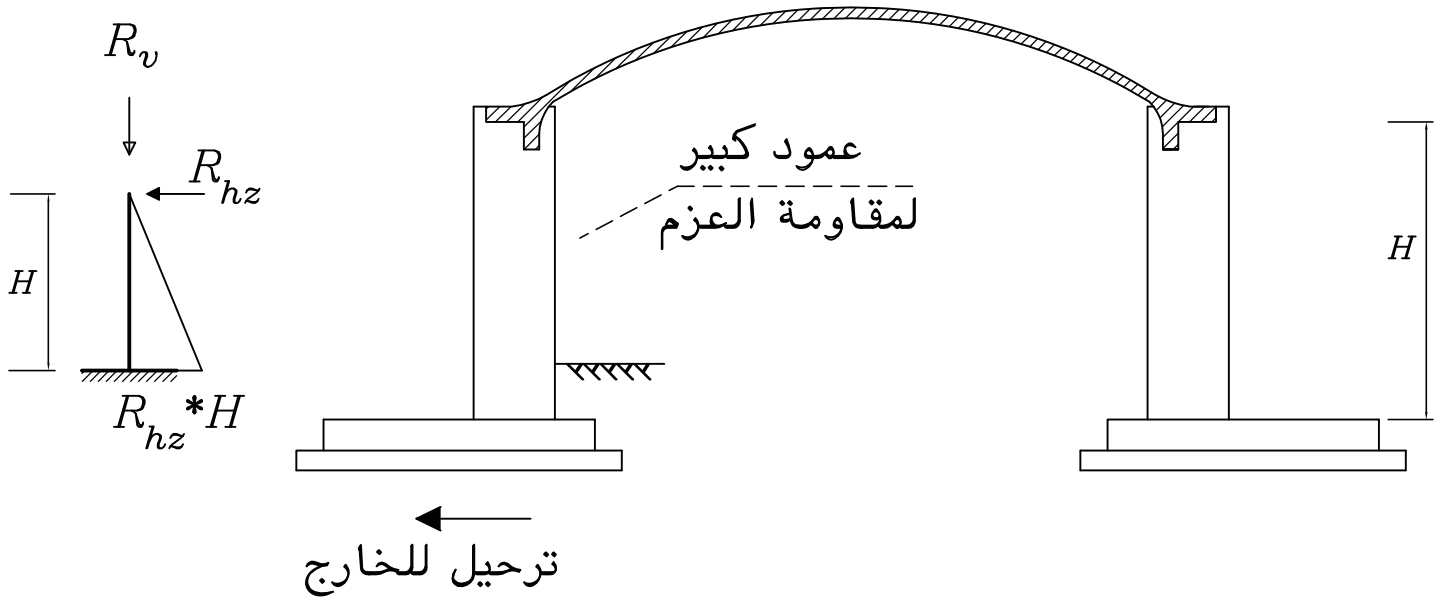
ترحيل للخارج

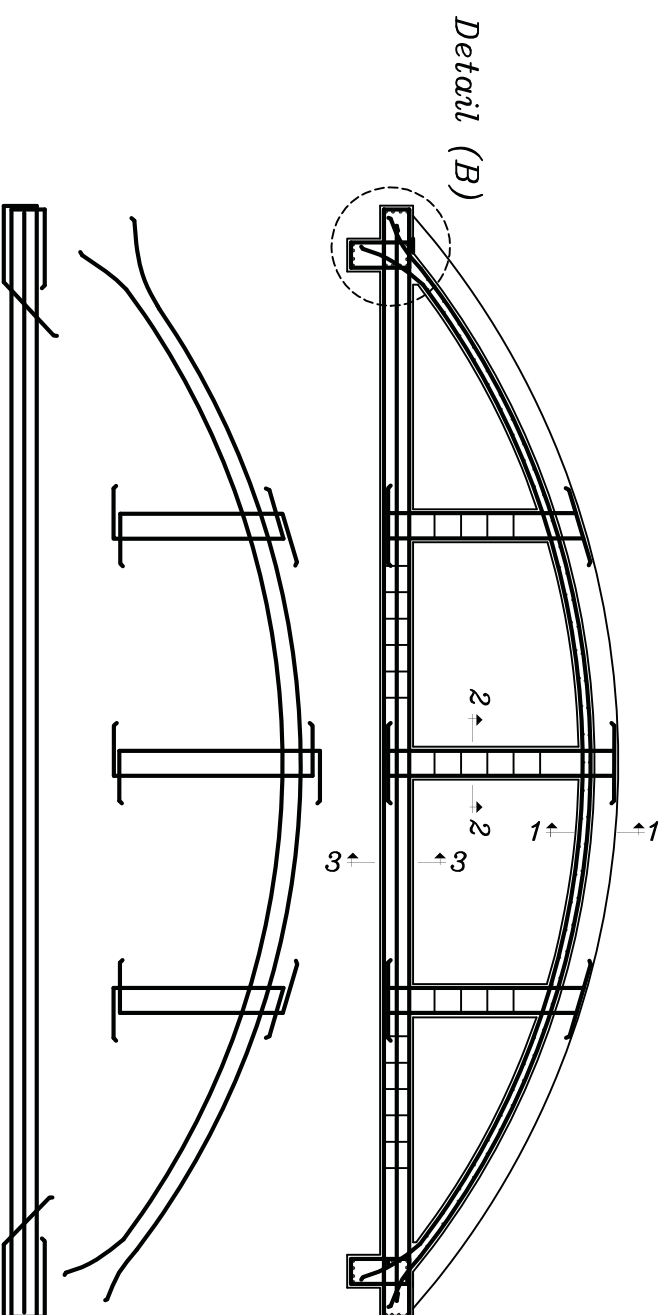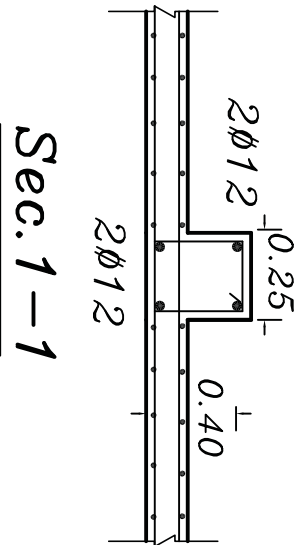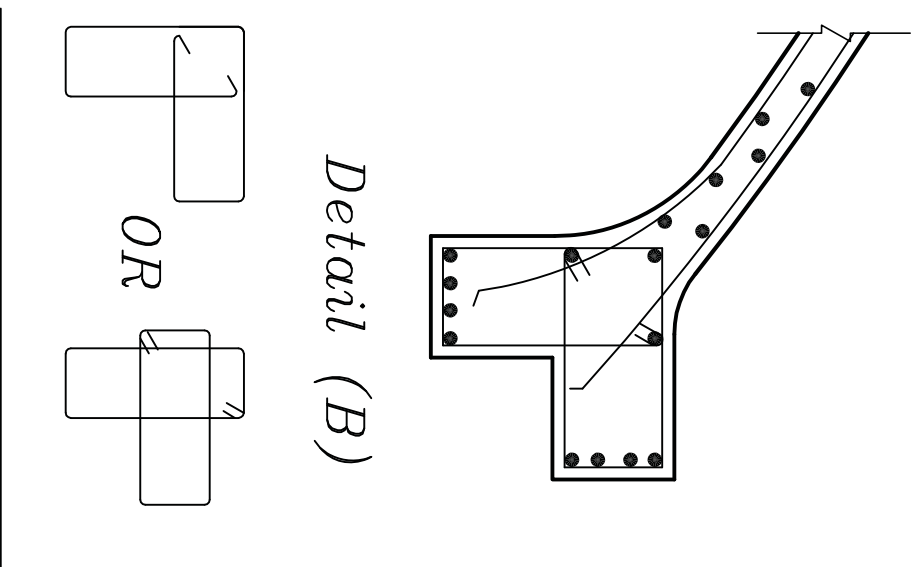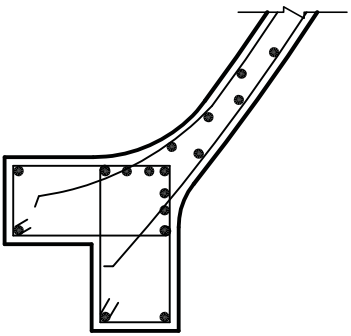لاحظ أن ترحيل القواعد للخارج نتيجة القوة الافقية على العمود

2- Continuous Arch Slab without tie
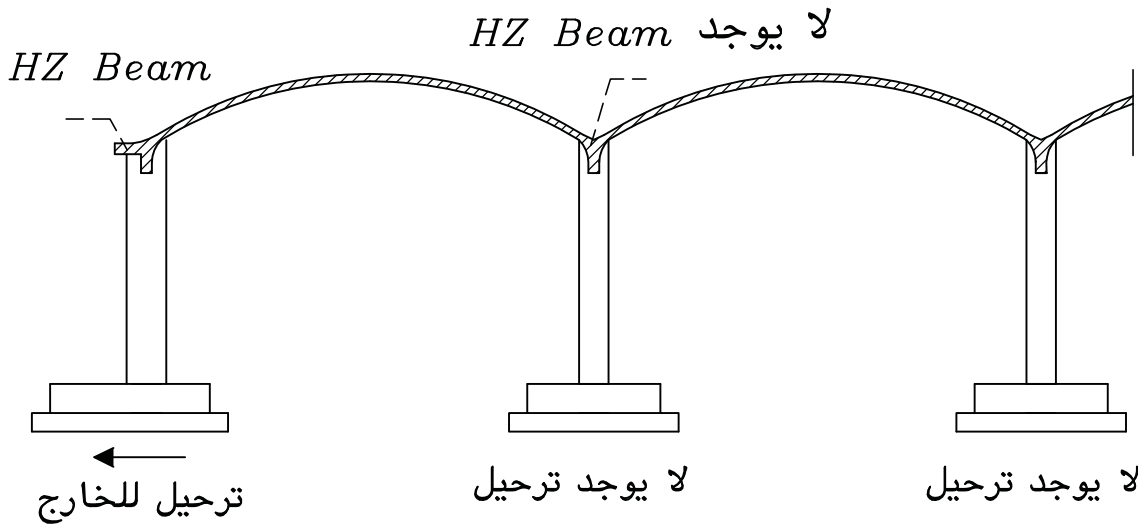
HZ Beam

لا يوجد HZ Beam

HZ Beam

ترحيل للخارج

لا يوجد ترحيل

لا يوجد ترحيل

-لاحظ أن البواكى الداخلية لا يوجد بها كمرة أفقية لان القوى الافقية تلاشى بعضها

-الاعمدة الداخلية لا يوجد بها ترحيل والاعمدة الخارجية يوجد بها ترحيل للخارج

R_v

R_{hz}

H

عمود خارجى

$R_{hz}*H$

$2R_v$

H

عمود داخلى

3- Continuous Arch Slab with tie

HZ Beam

لا يوجد HZ Beam

لا يوجد ترحيل   لا يوجد ترحيل   لا يوجد ترحيل

-لاحظ أن البواكى الداخلية لا يوجد بها كمرة أفقية لان القوى الافقية تلاشى بعضها

-الاعمدة الداخلية و الخارجية لا يوجد بها ترحيل .

R_v $2R_v$

H عمود خارجى H عمود داخلى
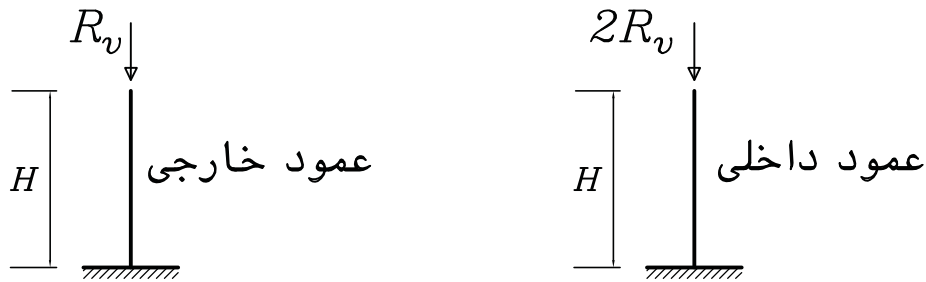
4- HZ Slab Connected to Arch Slab

ترحيل للخارج   لا يوجد ترحيل
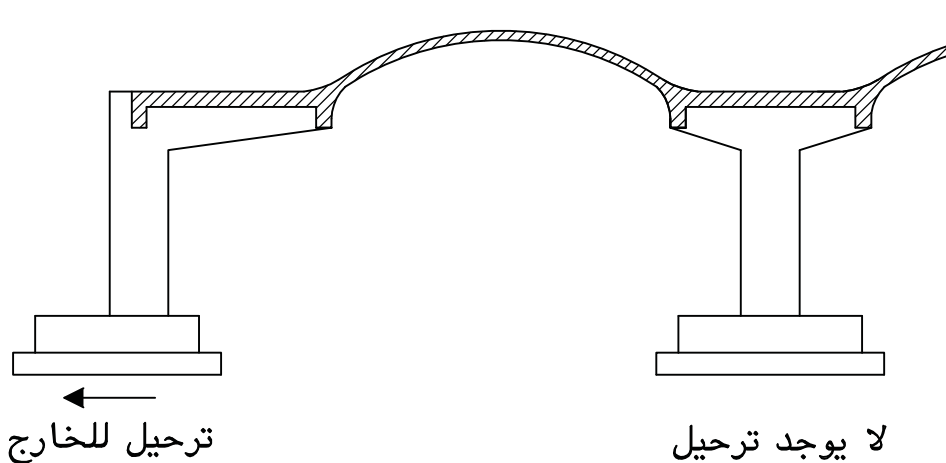
لا يوجد كمرة أفقية لان البلاطة تقوم بنفس عمل الكمرة الافقية

For HZ Slab

Strip 1.00m width

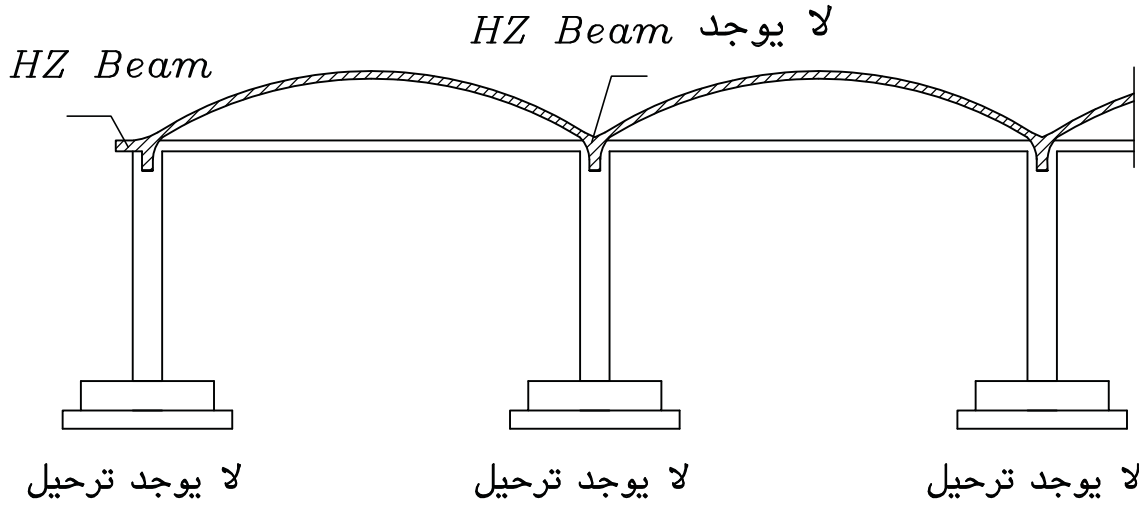$\boxed{B.M.D.}$ $\boxed{N.F.D.}$ $\boxed{B.M.D.}$ $\boxed{N.F.D.}$
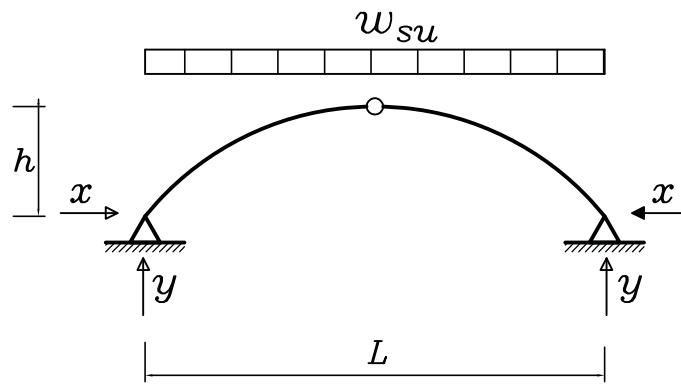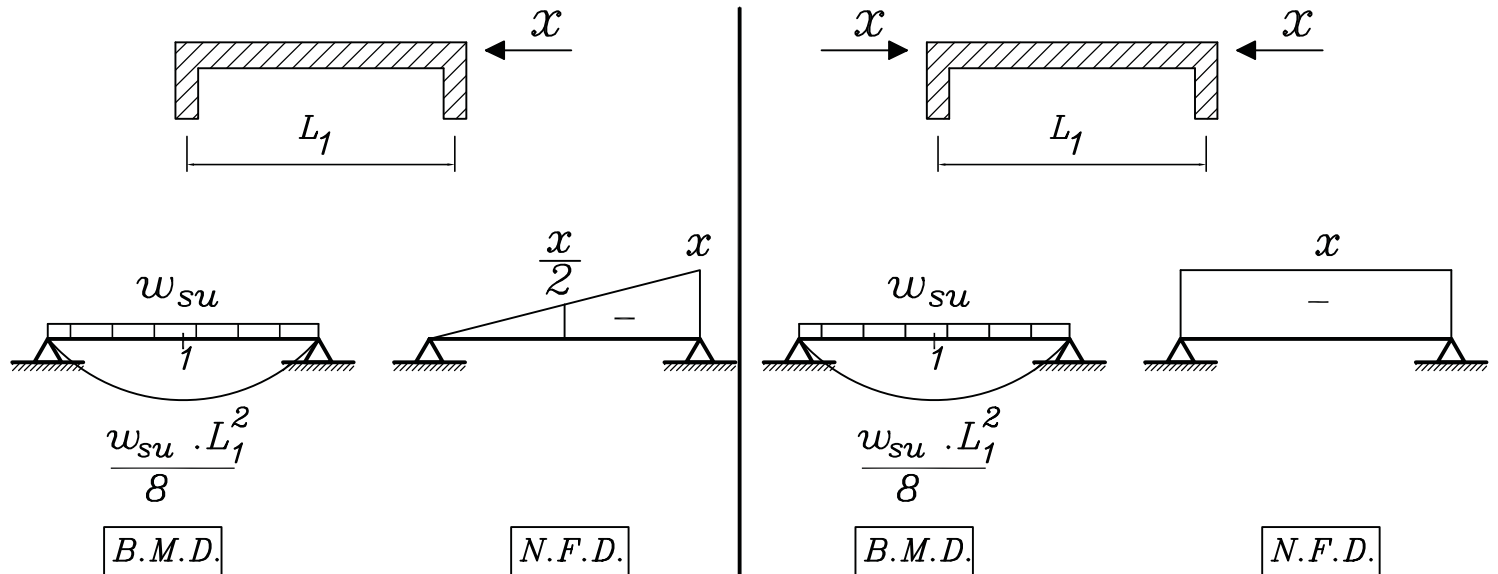
Sec.(1-1)

$$M = \frac{w_s \cdot L_1^2}{8} \qquad N = \frac{x}{2}$$

Sec.(1-1)

$$M = \frac{w_s \cdot L_1^2}{8} \qquad N = x$$

5- Inclined beam

Inclined beam

θ

تقوم (inclined beam) بعمل كلا من الكمرة الافقية والرأسية معا أى أن

$$w_{su}$$

$$h$$ $$x \rightarrow$$ $$\leftarrow x$$

$$R \nearrow$$ $$\uparrow y$$ $$\uparrow y$$

$$L$$
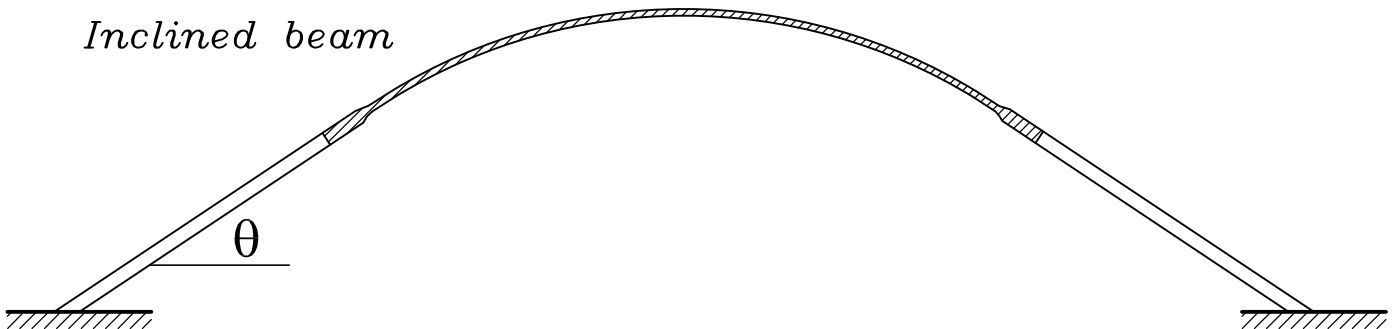
Strip 1.00m width

$$\boxed{R = \sqrt{x^2 + y^2}}$$ $$\boxed{\theta = tan^{-1}\left(\frac{y}{x}\right)}$$ $$R \quad x \quad \theta \quad y$$

$$w_i = R + o.w \ \ kN/m$$

$$R_i = w_i * spacing$$

$$w_i \ kN/m'$$ *Inclined beam*

spacing   *spacing*

$$R_i$$

$$R_i$$

$$R_i$$

$$R_i$$
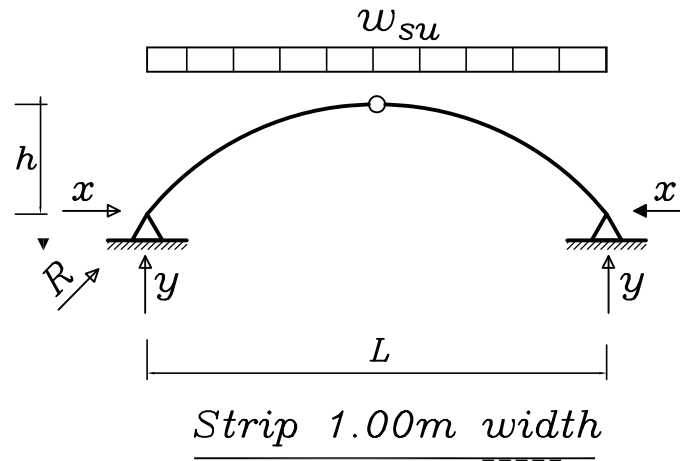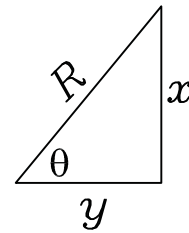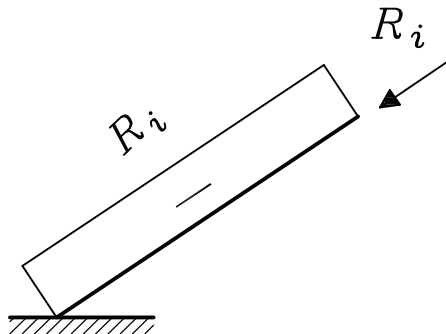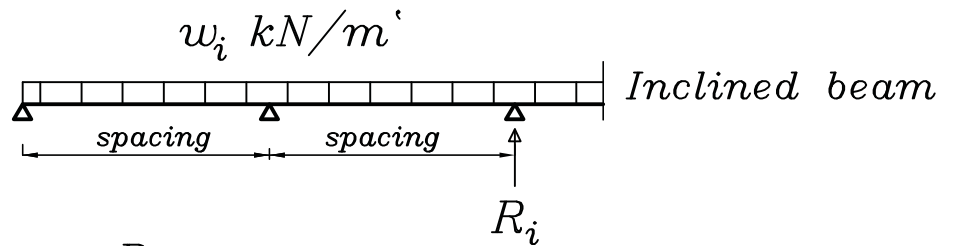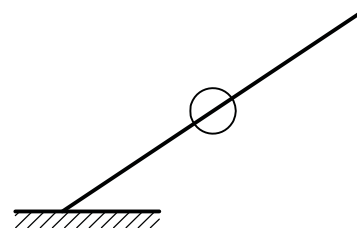
$$\boxed{N.F.D.}$$ $$\boxed{B.M.D.}$$

يصمم قطاع العمود على (N.f.) فقط.

لاحظ أننا لا نحتاج لوجود (Tie) لان محصلة القوى الرأسية والافقية فى اتجاه

العمود.

By Eng. Ezz El-Din Mostafa & Eng. Yasser M. Samir

Example

For the given plan and cross-section,

it is required to:

1 – Design the arch slab and draw plan of Rft.

2 – Design the main supporting element and draw details of Rft.

$35m$

$14m$

$F.C.+L.L.=1.0 kN/m^2$ (per hz proj.)

$f_{cu}=25 \ N/mm^2 \qquad f_y =360 \ N/mm^2$

(6.00)

(0.00)

$14m$
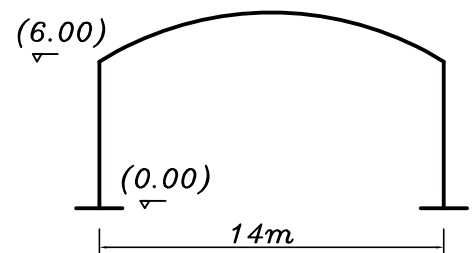
Sec.(1–1)

Solution

$w_{su} =(t_s \gamma_c +F.C.+L.L.)*1.5 \ kN/m^2$ per hz projection
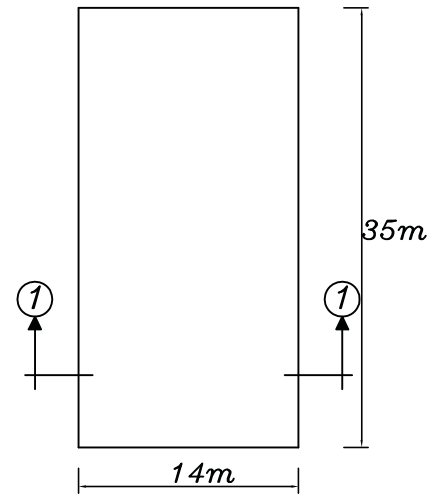
$w_{su} =(0.12*25+1.0)*1.5$

$w_{su} =6.0 \ kN/m^2$

$y=\dfrac{6.0*14}{2} \quad =42.0 \ kN/m^`$

$x=\dfrac{6.0*14^2}{8*2} \quad =73.5 \ kN/m^`$

$R=\sqrt{x^2+y^2}$

$R=\sqrt{42^2+73.5^2} =84.65 \ kN/m^`$

6.0kN/m

2.0m

x

y

x

y

14.0m

Strip 1.00m width

5.00m 5.00m

(8.00)

(6.00)
(4.00)
(0.00)
(−1.50)

0.25

0.30

(0.00)

Elevation

0.60

0.40

0.30

0.25

0.12

14.00m

0.16

2.00

KEY PLAN

1:200 → 1:400

5.00m

B(250*500)

Tie(300*300)

B(250*500)

Plan

73.50kN

84.65kN

$\boxed{N.F.D.}$
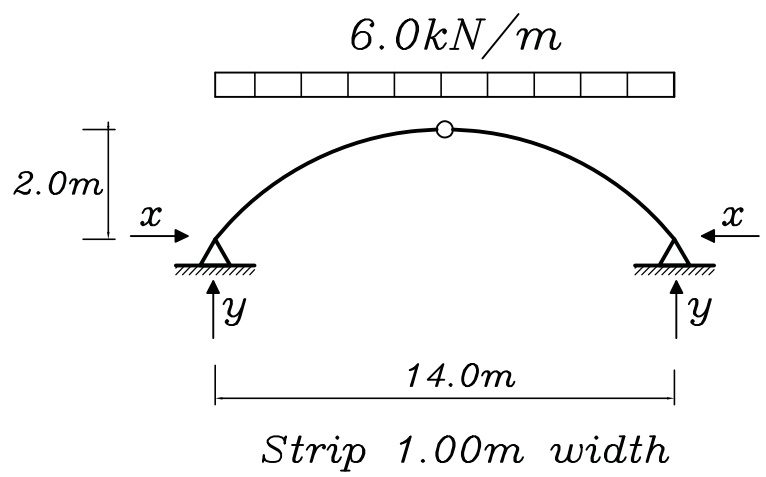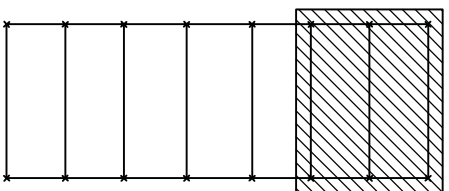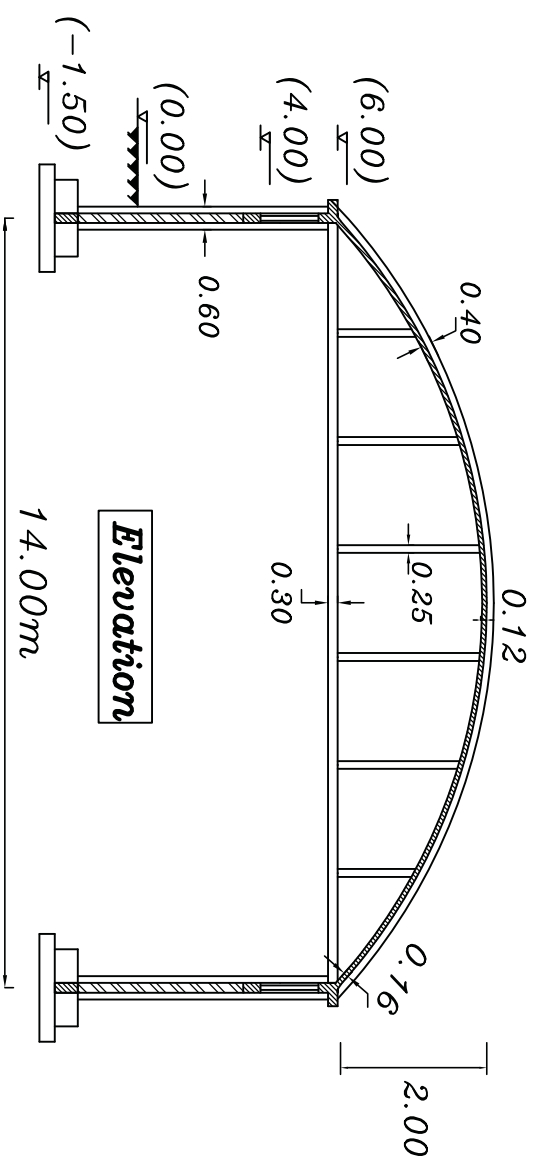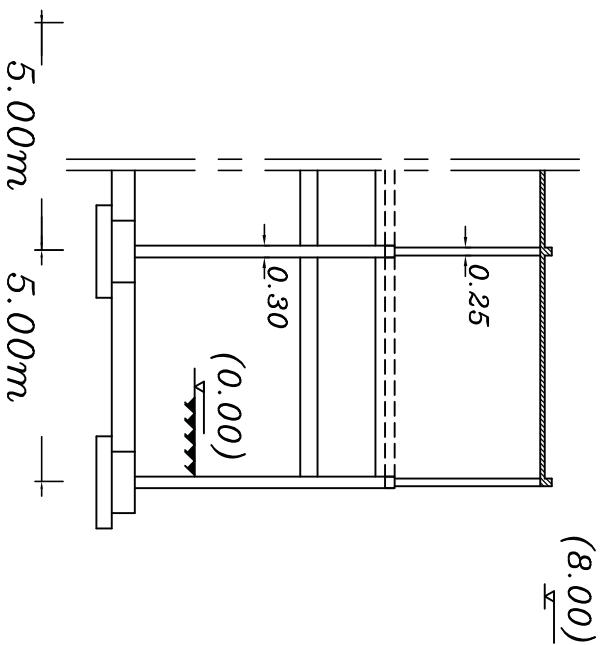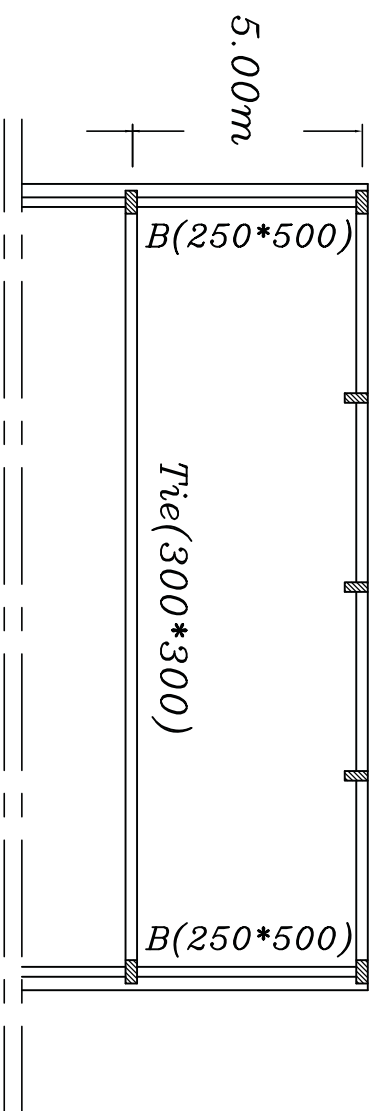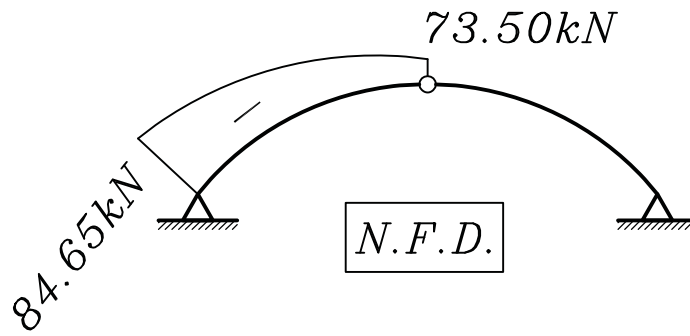
1-Design of Arch slab:

$R = 0.35 \; A_c \, f_{cu} + 0.67 \; A_s \, f_y$

$84.65*10^3 = 0.35 \; (1000*120)*25 + 0.67 A_s*360$

$A_s = -ve \;\; \longrightarrow \;\; A_{s_{min}} = \frac{0.6}{100} \; 1000*120 = 720mm^2$

$A_s = 5\phi10/m \; (T\&B)$

2-Design of VL.Beam

$w_v = y + o.w \;\; kN/m$

$w_v = 42 + \underbrace{0.25*0.50*25*1.40}_{o.w. \; of \; VL. \; beam} + \underbrace{0.30*0.60*25*1.40}_{o.w. \; of \; HZ. \; beam}$

$w_v = 52.68 \;\; kN/m$

$R_v = 52.68*5.0 = 263.38kN$

y kN/m

x kN/m

131.7   131.7   109.7

4   1   3   2

109.7   82.3

52.68 kN/m'

5.0m   5.0m

263.38kN
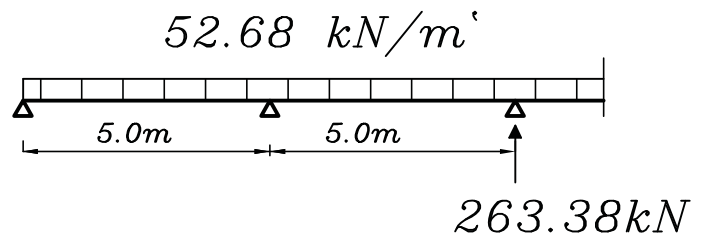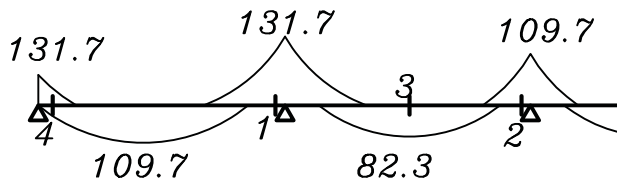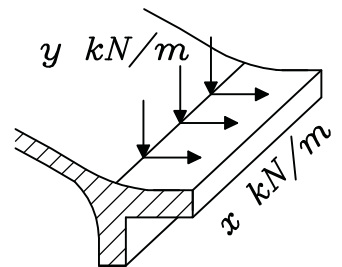
Sec 1

$450 = C_1 \sqrt{\dfrac{131.7*10^6}{250*25}} \;\; \Longrightarrow \;\; C_1 = 3.1 \quad J = 0.752$

$A_s = \dfrac{131.70*10^6}{0.752*450*360} = 10.81cm^2 = 5\phi16$

Sec 2	$=5\phi16$
Sec 3	$=4\phi16$
Sec 4	$=2\phi16$

3-Design of HZ.Beam

$w_{hz}=73.50 \ kN/m$

$R_{hz}=73.50*5.0=367.5kN$

Sec 1

$550=C_1\sqrt{\dfrac{183.75*10^6}{300*25}}$

$C_1=3.5 \quad J=0.782$

$A_s=\dfrac{183.75*10^6}{0.782*550*360}=11.87cm^2$

$A_s=5\phi18$

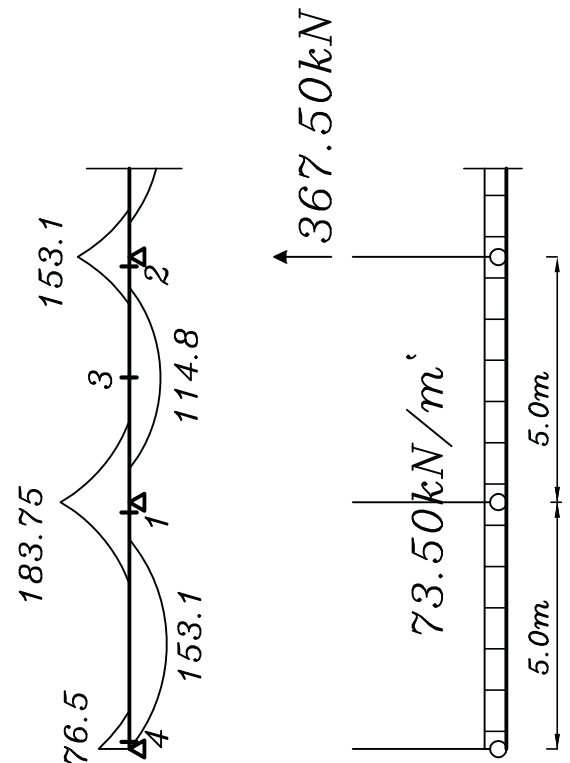| Sec 2	$=5\phi16$
Sec 3	$=4\phi16$
Sec 4	$=3\phi16$

From Check Shear use $8\phi10/m$ stirrups

4-Design of Tie

$T_{u.L.}=R_{hz}=367.5kN$

$A_s=\dfrac{367.5*10^3}{360/1.15}=11.74cm^2$

$A_s=6\phi16$

5-Design of hanger

$T = $ o.w of hanger + o.w of Tie .a

$T = 0.25^2 * 2 * 25 * 1.4 + 0.30^2 * 2.0 * 25 * 1.40 = 10.68 kN$

$A_s = \dfrac{10.68 * 10^3}{360 / 1.15} = 0.34 cm^2$

$A_s = 4 \phi 12$

Design of Columns (300*600)

$N_{ul.} = R_v = 263.38 kN$

$\lambda_{b_{in}} = \dfrac{1.3 * 6.75}{0.60} = 14.63$ $\qquad$ $\lambda_{b_{out}} = \dfrac{1.2 * 4.25}{0.30} = 17.00$

Buckling is outside plan

$\delta_b = \dfrac{\lambda_b^2 \, b}{2000} = \dfrac{17.00^2 * 0.30}{2000} = 0.04 m$

$M_{add} = 263.38 * 0.04 = 11.42 kN.m$

$\dfrac{N_{u.l.}}{bt f_{cu}} = \dfrac{263.38 * 10^3}{300 * 600 * 25} = 0.06$ $\qquad$ $\zeta = \dfrac{300 - 100}{300} = 0.67$

$\dfrac{M_{u.l.}}{bt^2 f_{cu}} = \dfrac{11.420 * 10^6}{600 * 300^2 * 25} = 0.008$
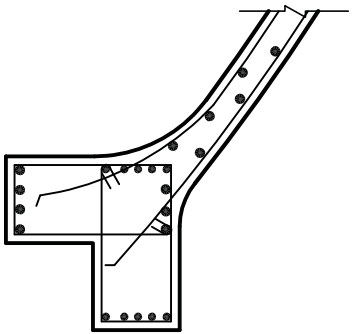
$\rho < 1$ Take $\rho = 1$

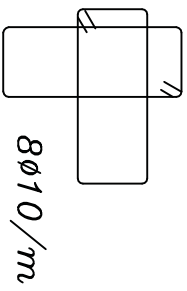$A_s = A_s' = 1 * 10^{-4} * 25 * 30 * 60 = 4.50 cm^2$

$A_{S\ min} = \dfrac{0.25 + 0.052 * 17.00}{100} * 30 * 60 = 20.41 cm^2$

$A_s = 8 \; \phi \, 18$

R.F.T. of the Arch slab

Detail (B)

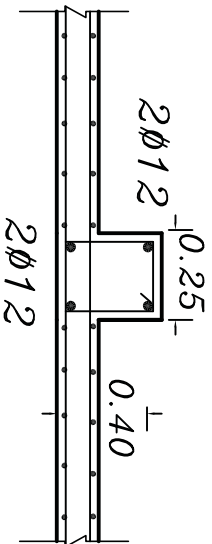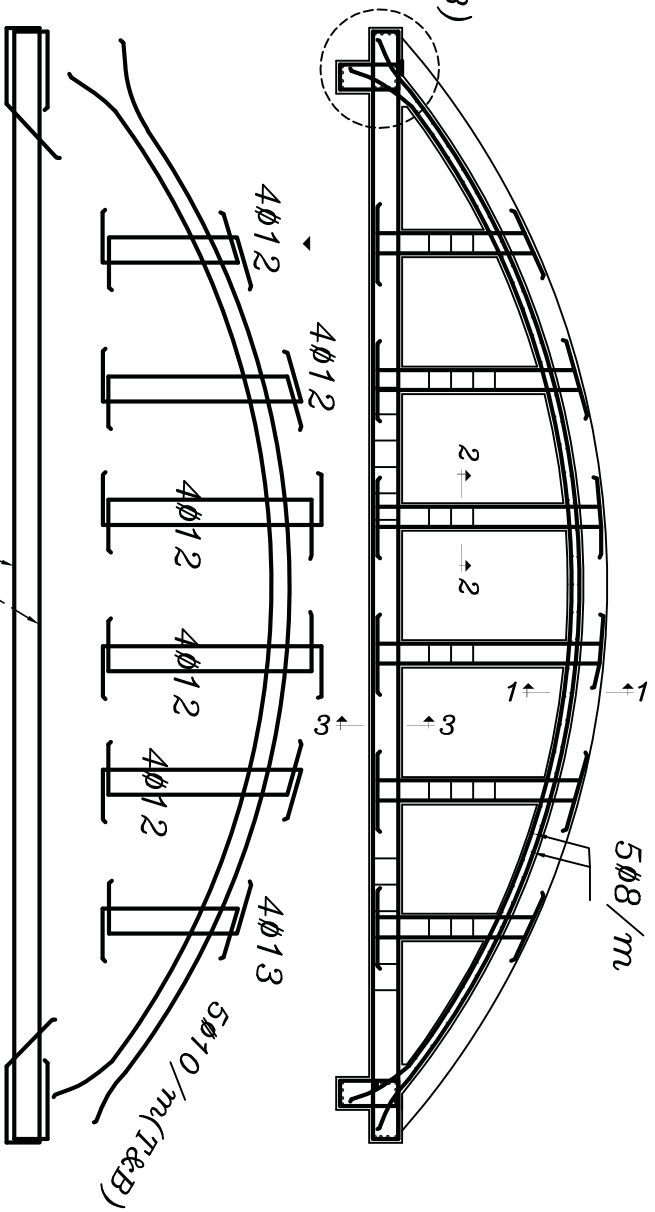8φ10/m

Sec.1-1

2φ12

2φ12

0.25

0.40

Detail (B)

4φ12

4φ12

3φ16

3φ16

4φ12

4φ12

2

2

4φ12

1

1

3

3

4φ12

4φ13

5φ8/m

5φ10/m(T&B)

Sec.2-2

0.25

0.25

4φ12

Sec.3-3

0.30

0.30

6φ16
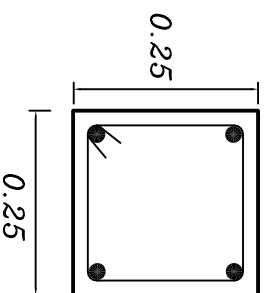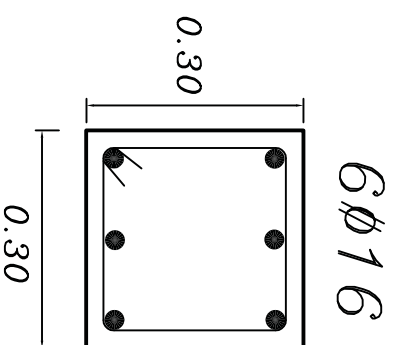
R.F.T. of the VL & HZ beams

Sec. 1-1

5φ18
3φ16
2φ10
5φ16

Sec. 2-2

2φ10
5φ16
3φ16
5φ16

Plan of Rft. for HL. Beam

3φ16
3φ16
2φ10
3φ18
2φ18
2φ16
2φ10
2φ16
3φ16

Elev. of Rft. for VL. Beam

2φ16
2φ10
3φ16
3φ16
2φ16
2φ16
2φ16
2φ10
2φ16
3φ16
2φ16
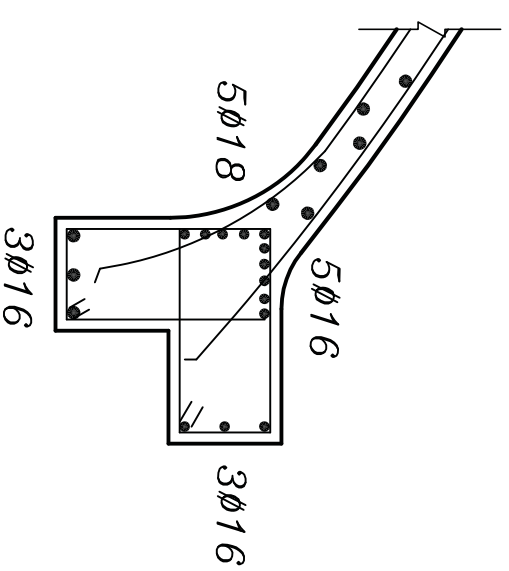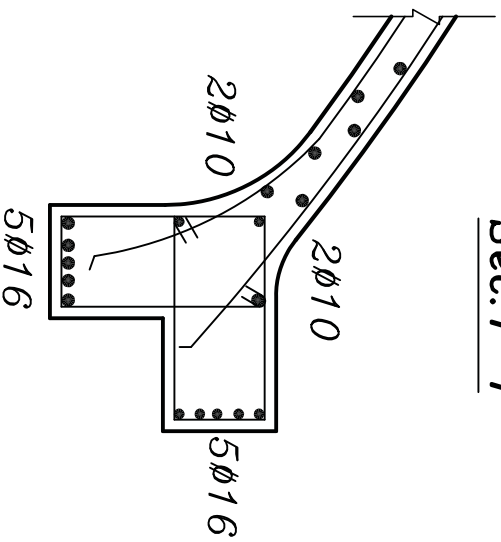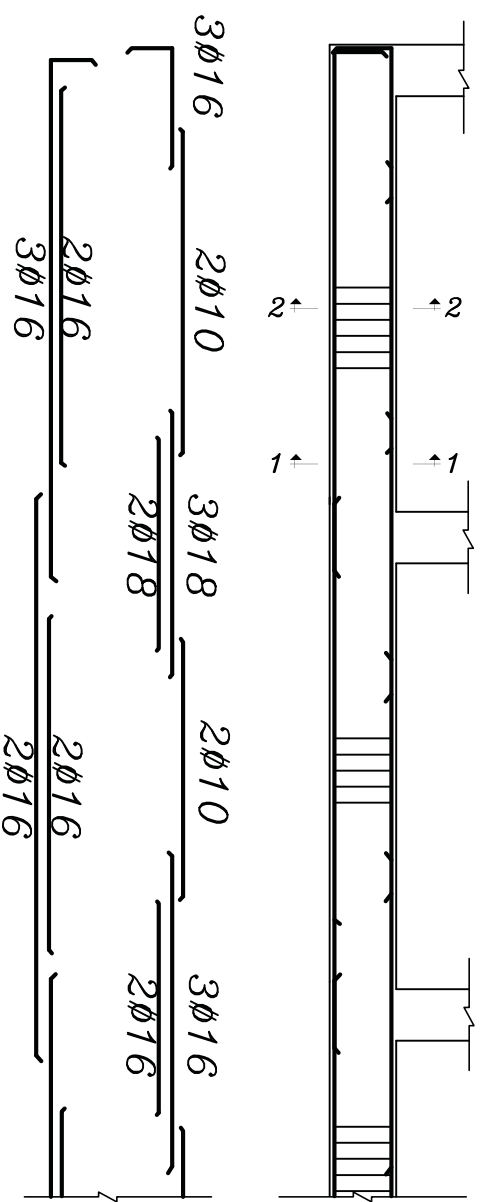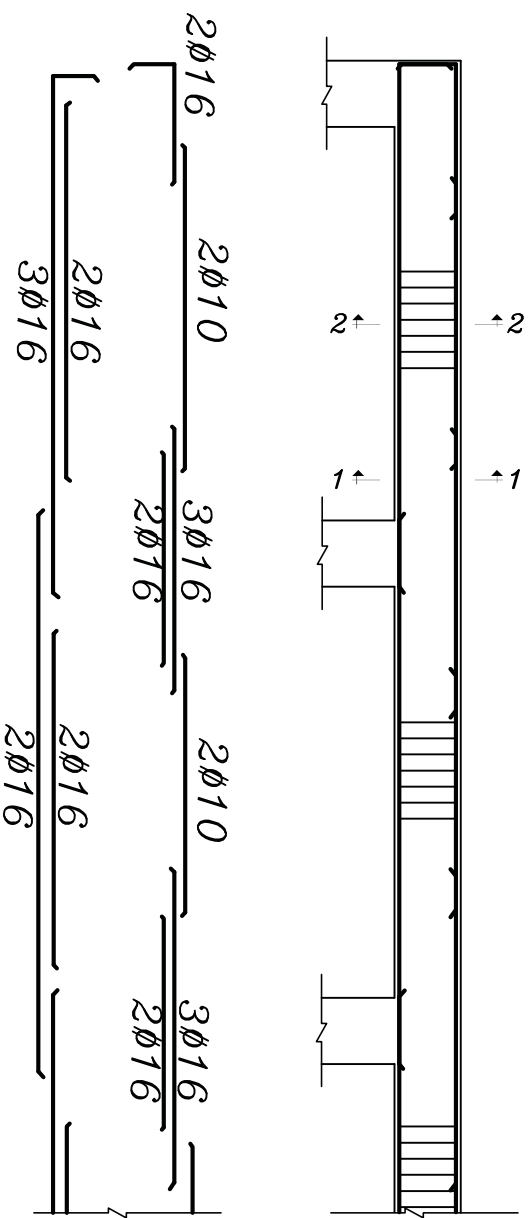
Example(2)

For the given plan and cross−section,

it is required to:

1−Design all the slabs and draw
  plan of Rft.

2−Design the main supporting element
   and draw details of Rft.

(Tie is not allowed)

$F.C.+L.L.=1.0 kN/m^2$ (for arched roof)

$F.C.+L.L.=2.5 kN/m^2$ (for hz roof)

$f_{cu}=25\ N/mm^2$ $f_y=360\ N/mm^2$ Sec.(1−1)
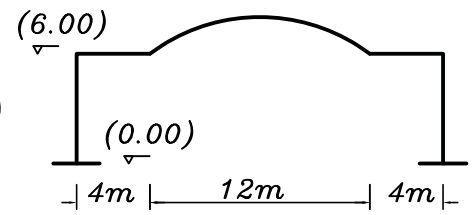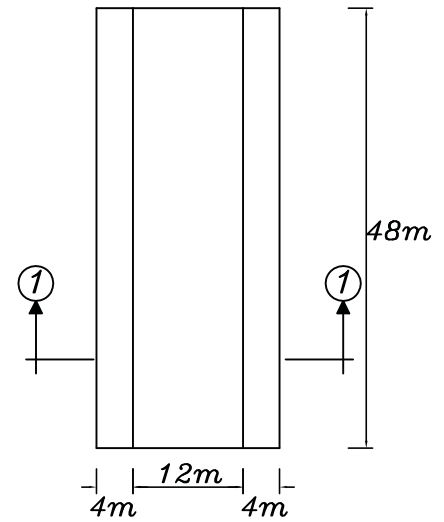
Solution

$w_{su} =(t_s\ \gamma_c\ +.FC..+L.L.)*1.5\ KN/m^2$ per hz projection

$w_{su} =(0.12*25+1.0)*1.5$

$w_{su} =6.0\ kN/m^2$

$y=\dfrac{6.0*12}{2}\ =36.0 kN/m`$

$x=\dfrac{6.0*12^2}{8*2}\ =54.0 kN/m`$

$R=\sqrt{x^2+y^2}$

$R=\sqrt{36.0^2+54.0^2}\ =64.90 kN/m$

Strip 1.00m width

54.00kN

64.90kN

$\boxed{N.F.D.}$
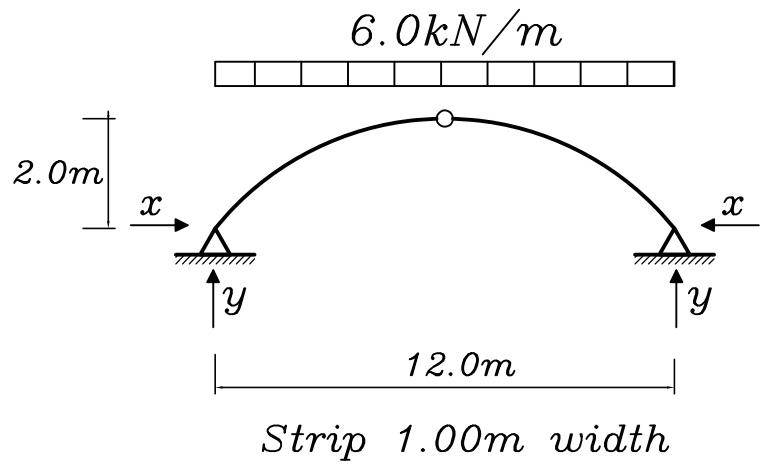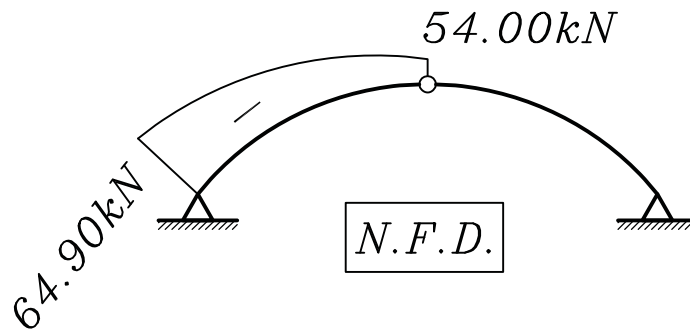
1-Design of Arch slab:

$R=0.35 \ A_c f_{cu} + 0.67 \ A_s f_y$

$64.90*10^3 = 0.35 \ (1000*120)*25 + 0.67 A_s *360$

$A_s = -ve \ \longrightarrow \ A_{s_{min}} = \frac{0.6}{100} \ 1000*120 = 720mm^2$

$A_s = 5\phi10/m \ (T\&B)$

2-Design of hz slab:

$w_{su} = (t_s \ \gamma_c \ +.FC..+L.L.)*1.5 \ KN/m^2$

$w_{su} = (0.12*25+2.5)*1.5$

$w_{su} = 8.25 \ kN/m^2$

Strip(1)

4.13kN/m

54kN/m

4m

2.75   **2.75**

1

8.25

$\boxed{B.M.D.}$

27.00   **54.00**

$\boxed{N.F.D.}$

strip2   β   α

strip1   β   α

strip3

r=1.14
α=0.42
β=0.27   6m

r=1.31
α=0.50
β=0.21   6m

4m
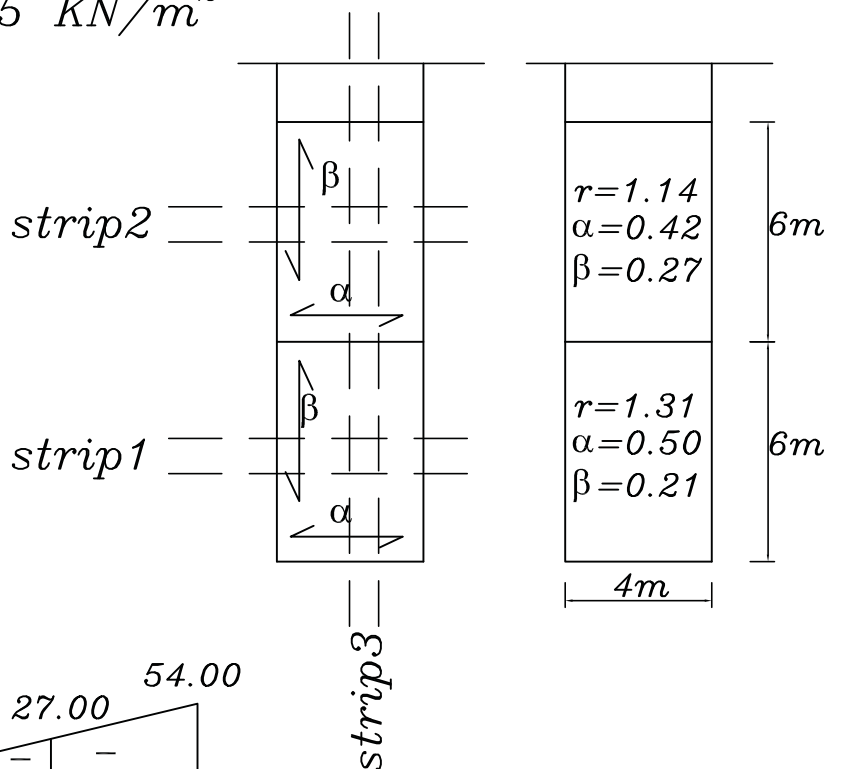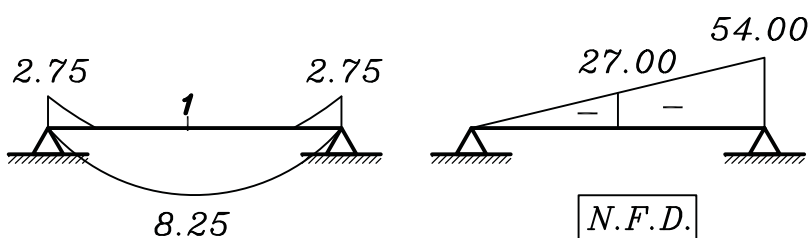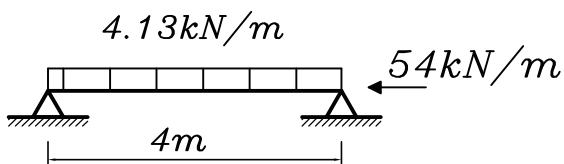
Sec. (1-1)

$$\frac{N_{u.l.}}{btf_{cu}} = \frac{27.00*10^3}{1000*120*25} = 0.009 < 0.04 \ (neglect \ N)$$

$$100 = C_1\sqrt{\frac{8.25*10^6}{1000*25}} \quad C_1 = 5.50 \quad J = 0.826$$

$$A_s = \frac{8.25*10^6}{0.826*360*100} = 2.77 cm^2/m'$$

$$A_s = 6 \ \phi \ 8/m'$$

Strip(2)

3.47kN/m

54kN/m

4m

2.31   1   2.31

6.93

27.00   54.00

N.F.D.

B.M.D.
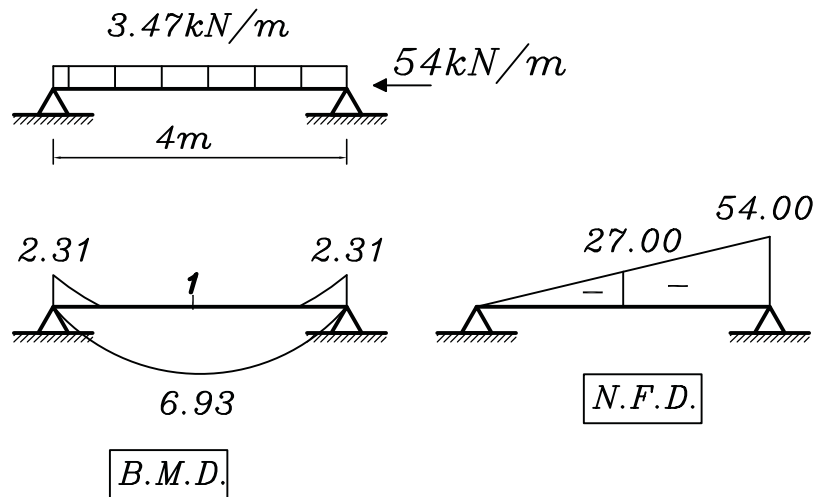
Sec. (1-1)
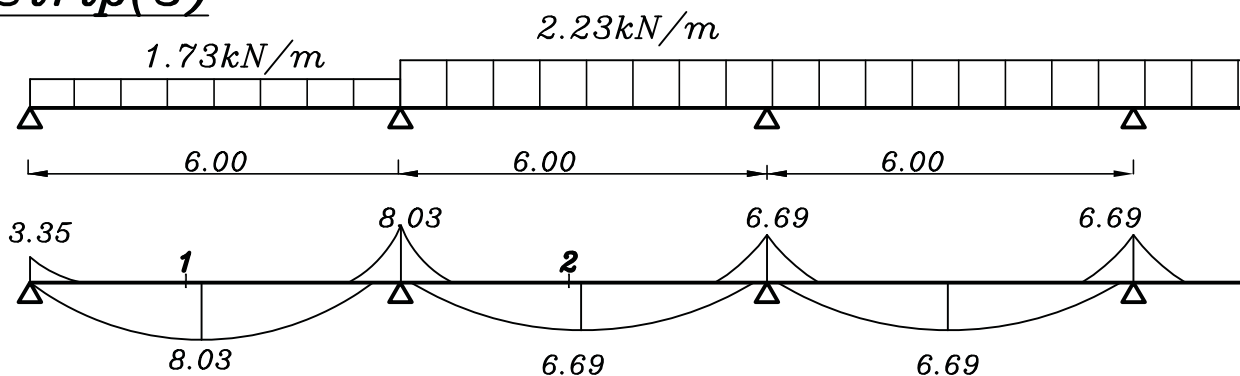
$$\frac{N_{u.l.}}{btf_{cu}} = \frac{27.00*10^3}{1000*120*25} = 0.009 < 0.04 \ (neglect \ N)$$

$$100 = C_1\sqrt{\frac{6.93*10^6}{1000*25}} \quad C_1 = 6.00 \quad J = 0.826$$

$$A_s = \frac{6.93*10^6}{0.826*360*100} = 2.33 cm^2/m'$$

$$A_s = 5 \ \phi \ 8/m'$$

Strip(3)

1.73kN/m   2.23kN/m

6.00   6.00   6.00

3.35   8.03   6.69   6.69

1   2

8.03   6.69   6.69

Sec. (1-1)
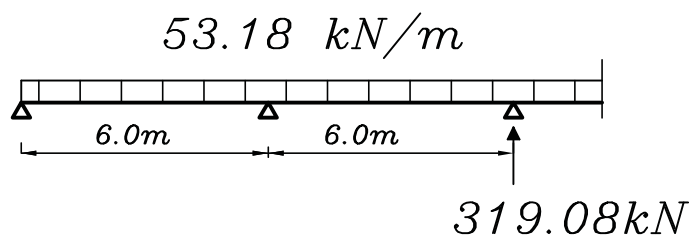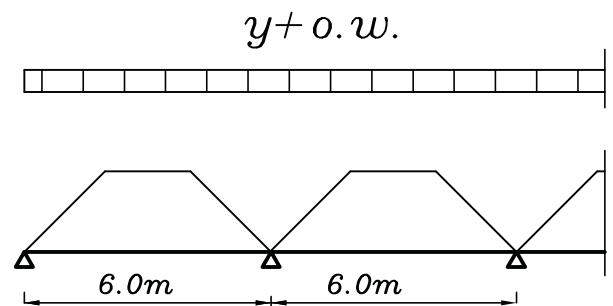
$A_s = 6 \phi 8/m'$

Sec. (2-2)

$A_s = 5 \phi 8/m'$

3-Design of VL.Beam

$$w_v = y + o.w + C_a \frac{L_s}{2} \ w_s \ KN/m \qquad \& \quad C_a = 1 - \frac{1}{2} \left(\frac{L_s}{L} \right)$$

$$w_v = 36 + 0.25*0.70*25*1.40 + 0.67*\frac{4.0}{2}*8.25$$

$$w_v = 53.18 \ kN/m$$

$$R_v = 53.18*6.0 = 319.08kN$$
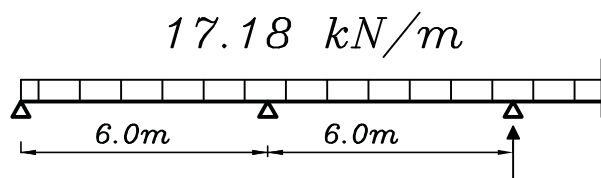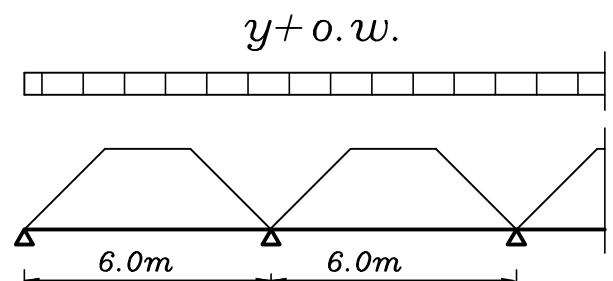

y + o.w.

6.0m   6.0m

53.18 kN/m

6.0m   6.0m

319.08kN

4-Analysis of B₂

$$w_2 = o.w + C_a \frac{L_s}{2} \ w_s \ KN/m$$

$$w_2 = 0.25*0.70*25*1.40 + 0.67*\frac{4.0}{2}*8.25$$

$$w_2 = 17.18 \ kN/m$$

$$R_2 = 17.18*6.0 = 103.08kN$$
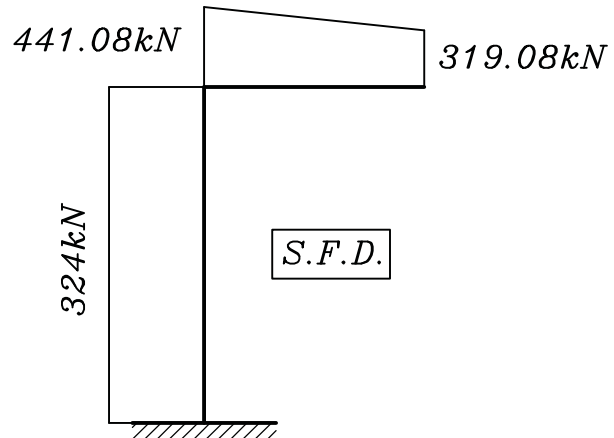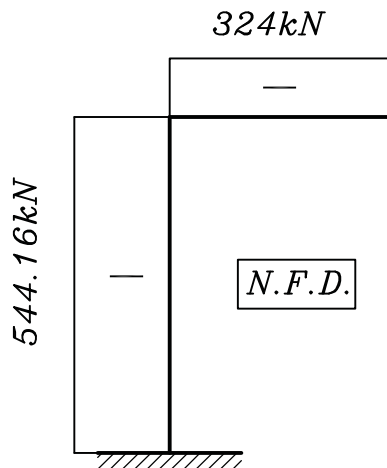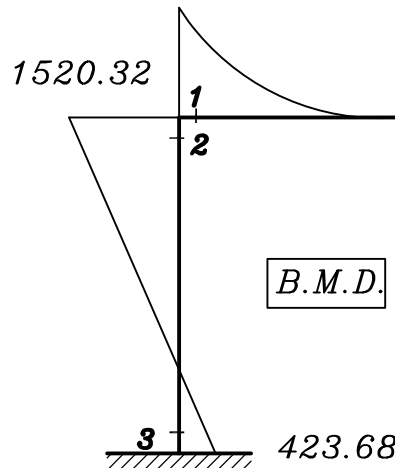

y + o.w.

6.0m   6.0m

17.18 kN/m

6.0m   6.0m

103.08kN

5-Design of the frame:

assume o.w.=10kN/m (working)

$$w_f = o.w + C_e \frac{L_s}{2} w_s *2 \quad KN/m$$

$$w_f = 10*1.40 + 0.50 * \frac{4.0}{2} *8.25*2$$

$$w_f = 30.50 \quad kN/m$$

103.08kN   319.08kN

54*6.0
=324kN

6.0m

4m

103.08kN   319.08kN

54*6.0
=324kN

30.5kN/m

6.0m

4m

1520.32

1
2

B.M.D.

3 423.68

324kN

—

544.16kN

— N.F.D.

441.08kN

319.08kN

324kN

S.F.D.
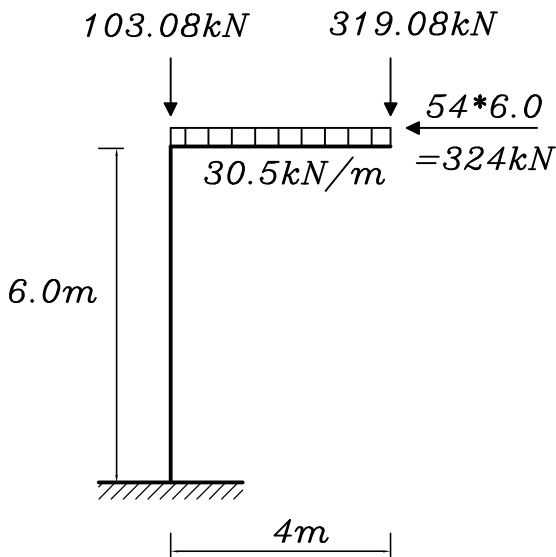
Sec(1-1)

$$d = 3.5 \sqrt{\frac{1520.32*10^6}{300*25}} \implies d = 1600mm. \quad \& \quad t = 1700mm$$

$$\frac{N_{u.l.}}{b \ t \ f_{cu}} = \frac{324*10^3}{300*1700*25} = 0.025 < 0.04(\ neglect \ N)$$

$$1600 = C_1 \sqrt{\frac{1520.32*10^6}{300*25}} \quad C_1 = 3.55 \quad J = 0.784$$

$$A_s = \frac{1520.32 * 10^6}{0.783 * 1600 * 360} = 33.67 cm^2$$

$$A_s = 10 \ \phi \ 22$$

Sec(2-2)

$$\frac{N_{u.l.}}{b \ t \ f_{cu}} = \frac{544.16 * 10^3}{300 * 1700 * 25} = 0.043 > 0.04 (Dont \ neglect \ N)$$

$$e = \frac{M_{u.l.}}{N_{u.l.}} = \frac{1520.32}{544.16} = 2.79m$$

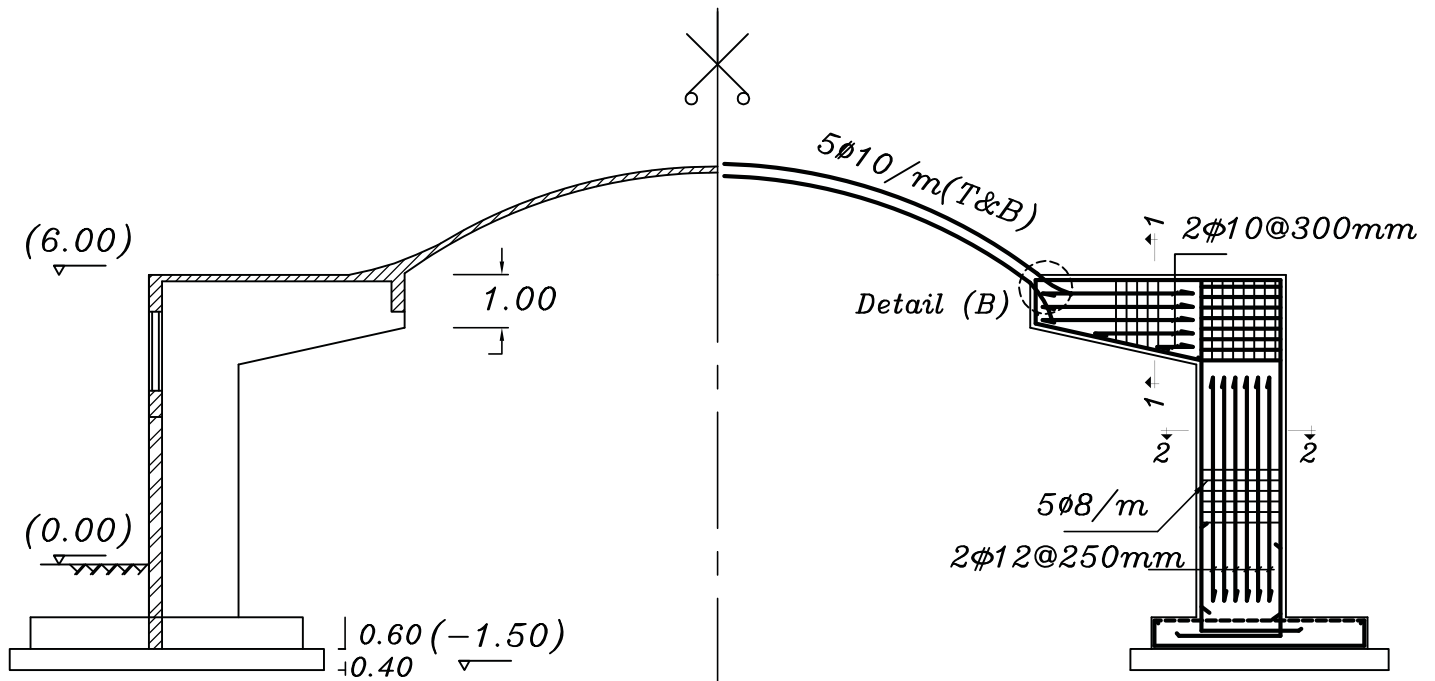$$\frac{e}{t} = \frac{2.79}{1.7} = 1.6 > 0.5 (big \ eccentricity)$$

$$e_s = e + \frac{t}{2} - c = 2.79 + \frac{1.7}{2} - 0.1 = 3.54m$$

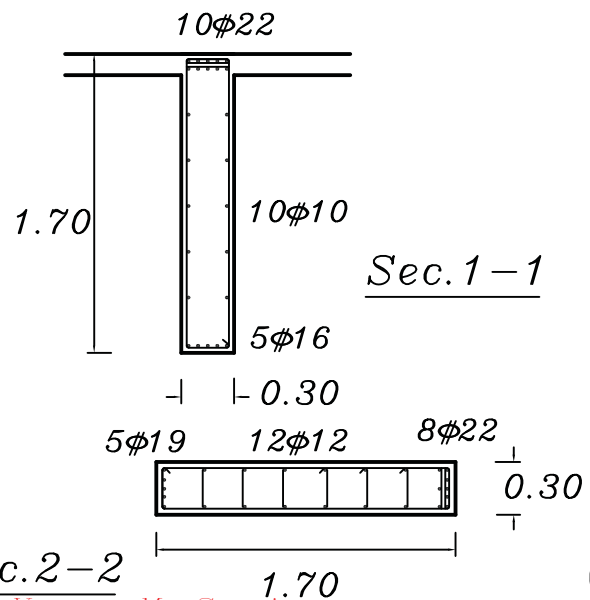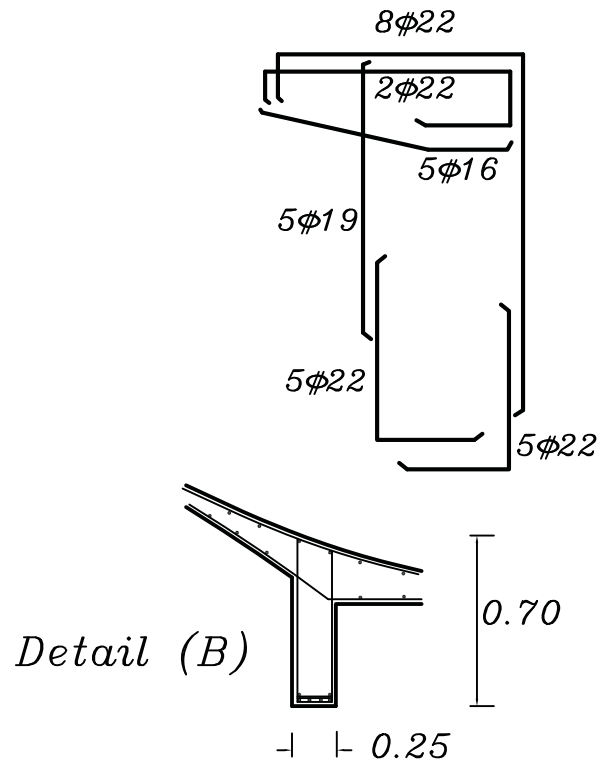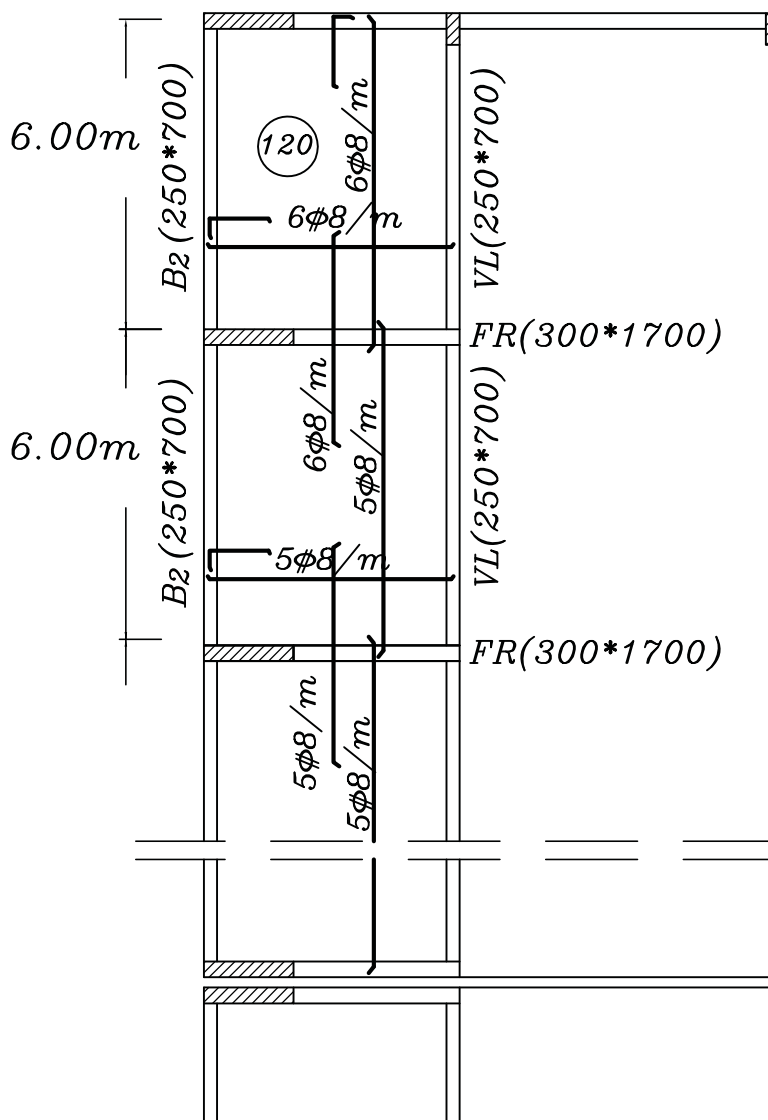$$M_{us} = N_{u.l.} * e_s = 544.16 * 3.54 = 1928.44 kN.m$$

$$1600 = C_1 \sqrt{\frac{1928.44 * 10^6}{300 * 25}} \quad C_1 = 3.16 \quad J = 0.76$$

$$A_s = \frac{1928.44 * 10^6}{0.76 * 1600 * 360} - \frac{544.16 * 10^3}{360/1.15} = 26.84 cm^2$$

$$A_s = 8 \ \phi \ 22$$

(6.00)

1.00

$5\phi10/m(T\&B)$

$2\phi10@300mm$

Detail (B)

(0.00)

$5\phi8/m$

$2\phi12@250mm$

0.60 (−1.50)

0.40

4.0m 6.0m

$8\phi22$

$2\phi22$

$5\phi16$

$5\phi19$

$5\phi22$

$5\phi22$

6.00m

120

$6\phi8/m$

$B_2(250*700)$

$6\phi8/m$

$VL(250*700)$

$FR(300*1700)$

$6\phi8/m$

$5\phi8/m$

$VL(250*700)$

6.00m

$B_2(250*700)$

$5\phi8/m$

$VL(250*700)$

$FR(300*1700)$

$5\phi8/m$

$5\phi8/m$

Detail (B)

0.70

0.25

$10\phi22$

1.70

$10\phi10$

Sec.1−1

$5\phi16$

0.30

$5\phi19$ $12\phi12$ $8\phi22$

0.30

Sec.2−2

1.70